Materials for Renewable Energy

Interdisziplinäres Zentrum für Materialwissenschaften

Martin-Luther-Universität Halle–Wittenberg

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Weinberg Campus

Technology and Founders' Center

Scientists – Founders – Entrepreneurs

Infrastructure for research institutes, the university and SME

Synergy for new technologies

Interdisciplinary Center of Materials Science (CMAT)

TGZ Bio–Nano Center

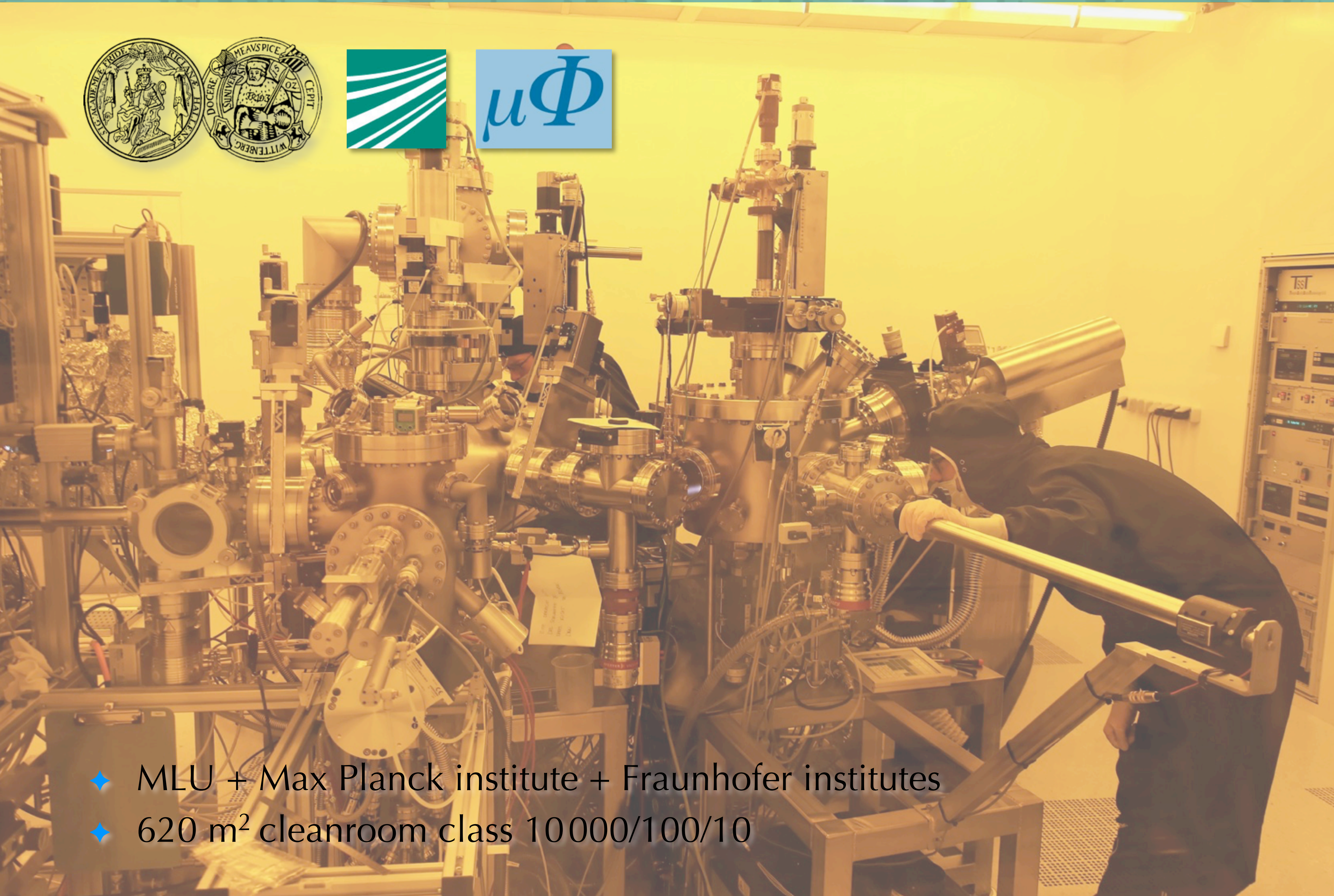
Research facility for physicists, chemists, materials scientists, biologists, pharmacists

Max Planck, Fraunhofer, SME

CMAT = nanotechnology pilot plant of the University

- Nanostructuring: lithography, thin film deposition, device prototyping
- Nanoanalysis: electron microscopy, optical characterization, positron annihilation
- 1800 m^2 labs, 620 m^2 cleanroom

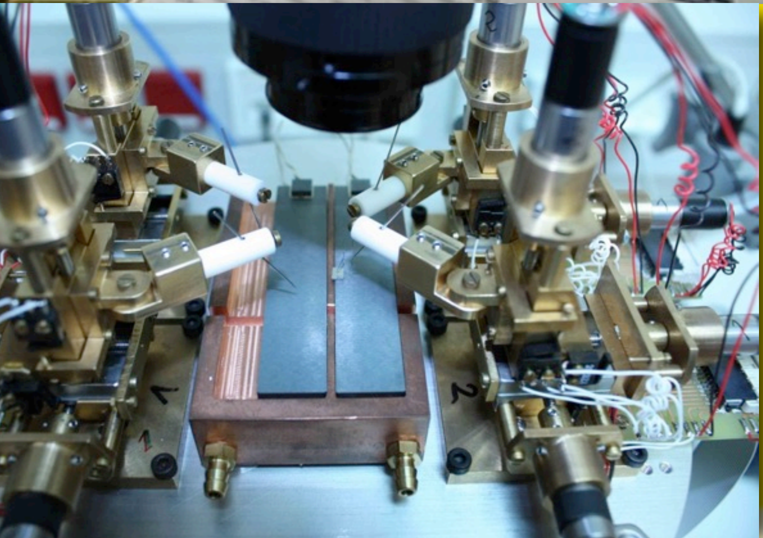
Cleanroom of *Nanotechnikum Weinberg*



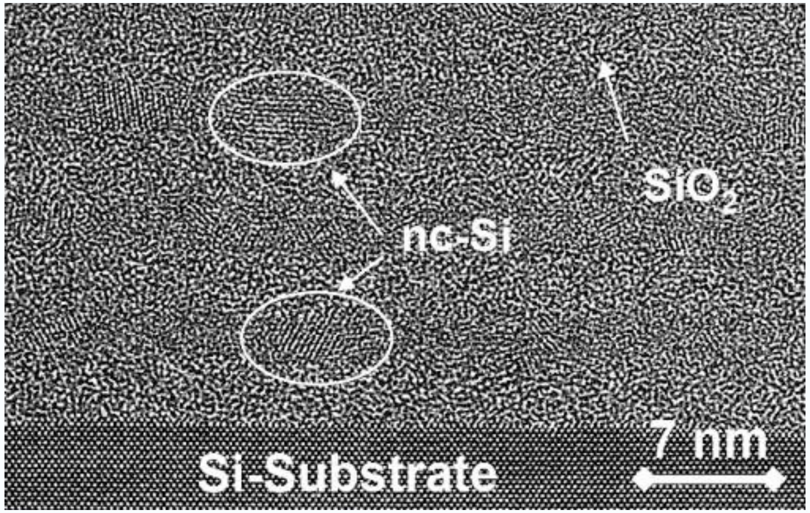
- MLU + Max Planck institute + Fraunhofer institutes
- 620 m^2 cleanroom class 10000/100/10

Analytical labs of *Nanotechnikum Weinberg*

- Various electron microscopes
- Raman microscopy, ellipsometry
- Positron annihilation
- Scanning probe microscopy
- Electrical/thermal transport measurements

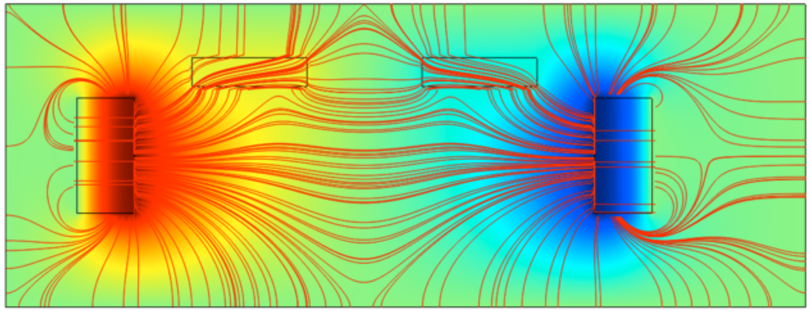


Renewable energy materials



✦ Silicon-based nanostructured thin film materials as functional elements for next-generation solar cells

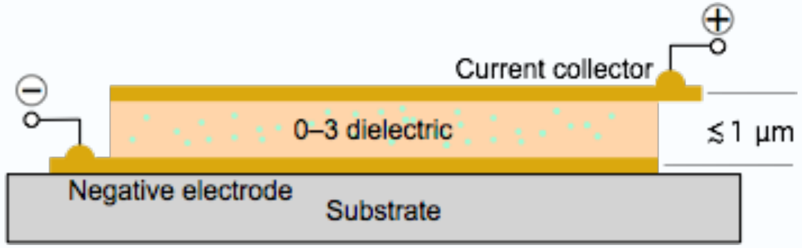
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung



WING
Werkstoffinnovationen für Industrie und Gesellschaft

✦ Si and Si–Ge thin films for thermoelectric applications

ForMaT
UNTERNEHMEN REGION
Die BMBF-Innovationsinitiative Neue Länder



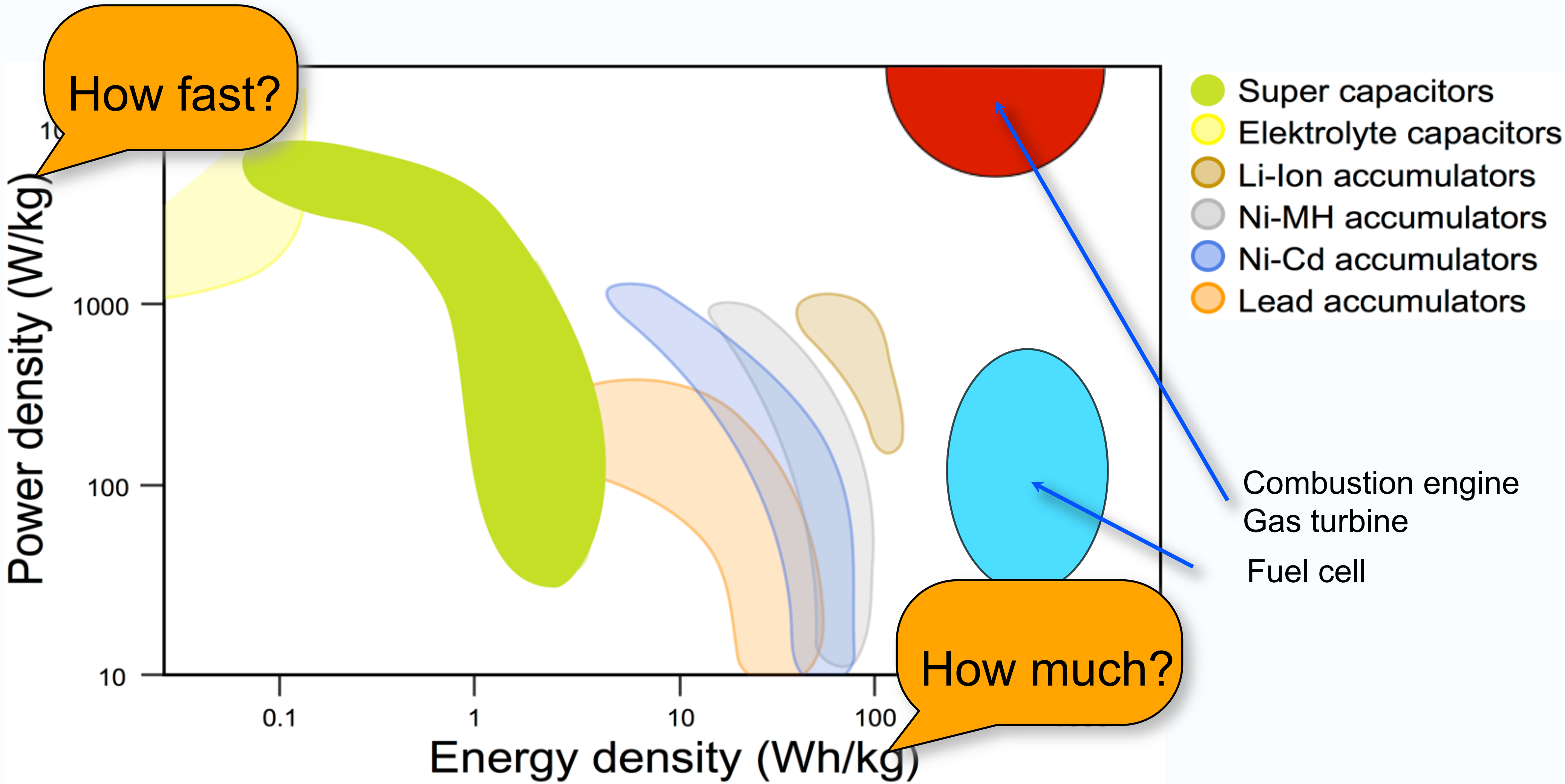
✦ New supercapacitors as energy storage devices

Energy concept of Saxony-Anhalt

"Energiestudie mit Prognosen der Energiekennzahlen für die Jahre 2020 und 2030 zur Vorbereitung der Fortschreibung des Energiekonzeptes der Landesregierung von Sachsen-Anhalt"

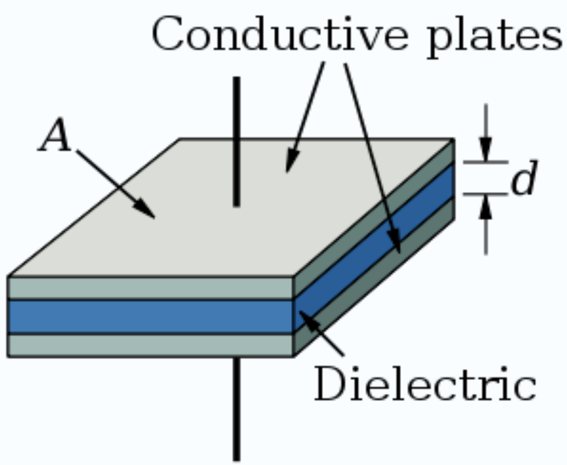
→ Demand for energy storage

Ragone diagram



Capacitors

Capacitance C = Amount of charge stored per unit voltage



$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

ε_0 vacuum permittivity $\approx 9 \cdot 10^{-12}$ F/m
ε_r relative static permittivity of the dielectric (sometimes called dielectric constant)

Energy stored: $$E = \frac{1}{2} C U^2 = \frac{1}{2} \varepsilon_r \varepsilon_0 \frac{A}{d} U^2$$

Commercially available standard capacitors

Ceramic capacitors

e. g. barium titanate

+ High permittivity
+ Thermal stability
+ High frequencies

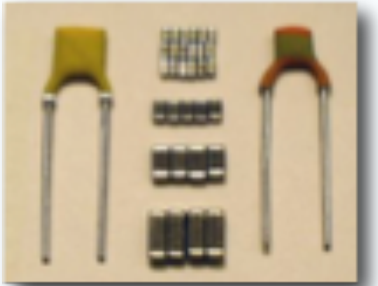
– Brittle

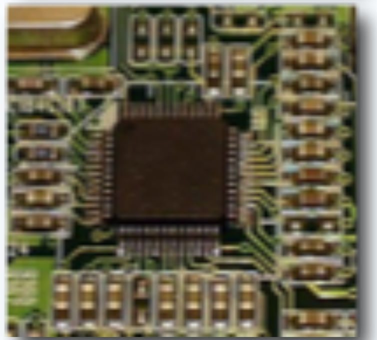
Thin-film polymer capacitors

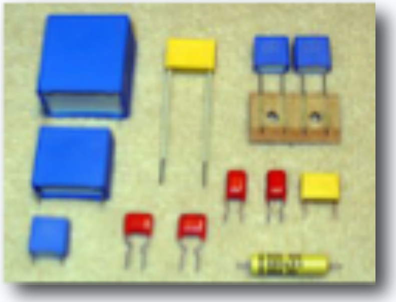
e. g. PET, PP

+ High voltage
+ Low conductivity
+ Simple shapes

– Low permittivity

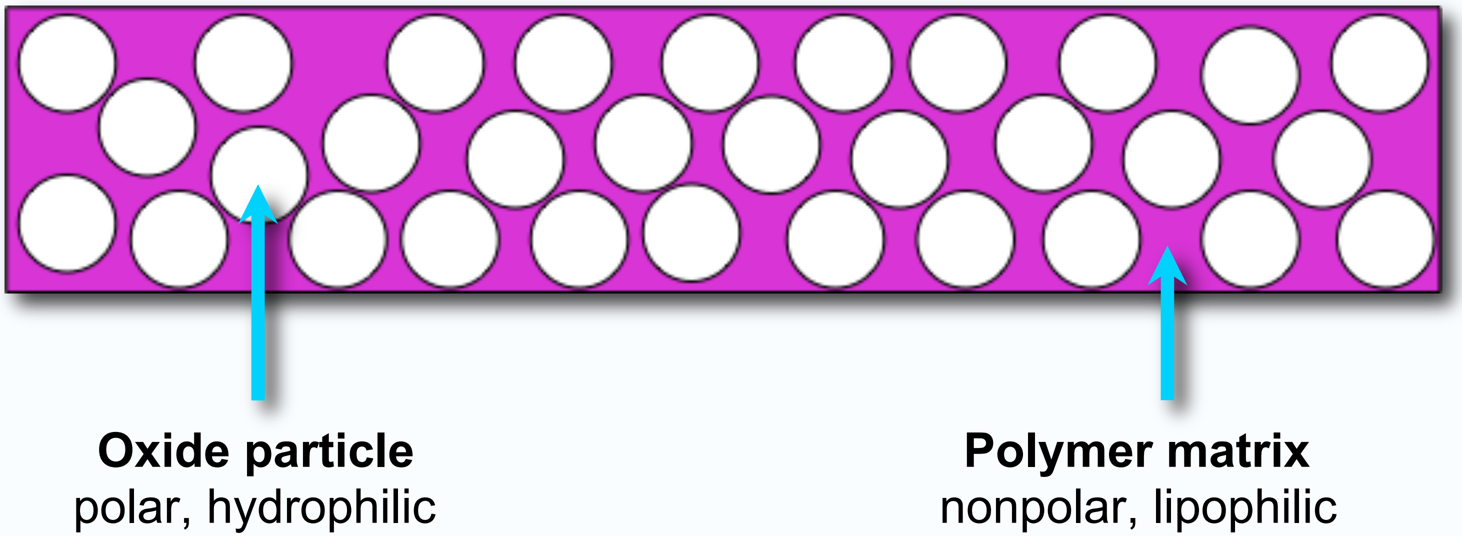


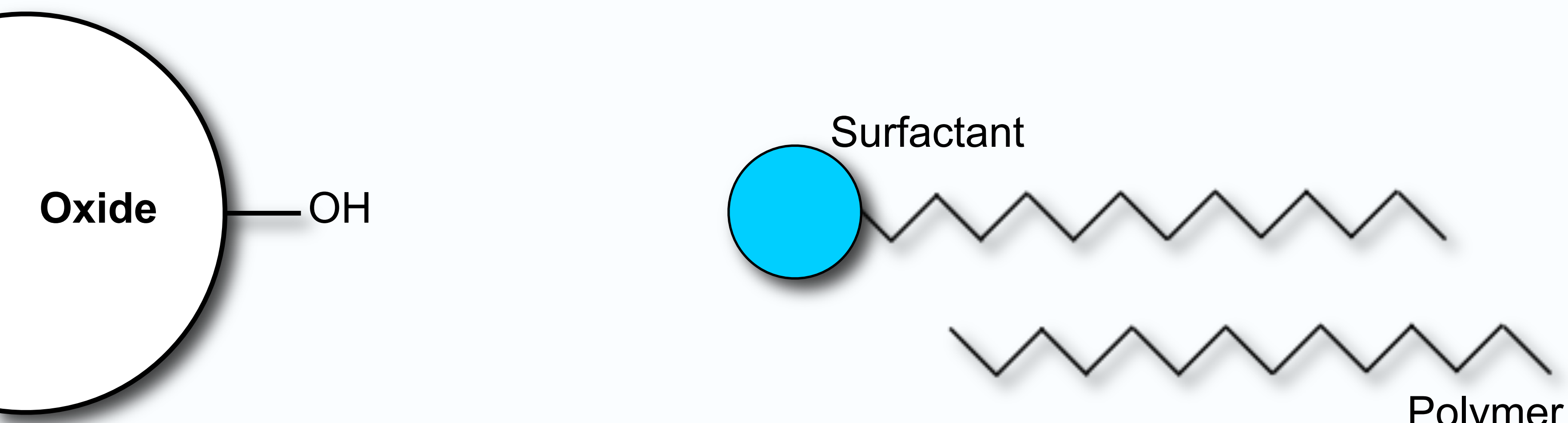




Composite capacitors

Composite dielectrics

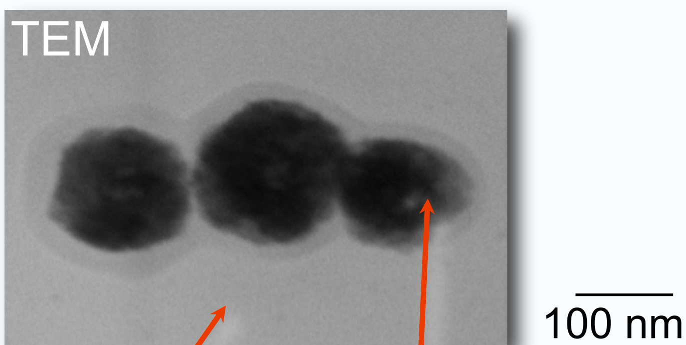




0–3 nanocomposites

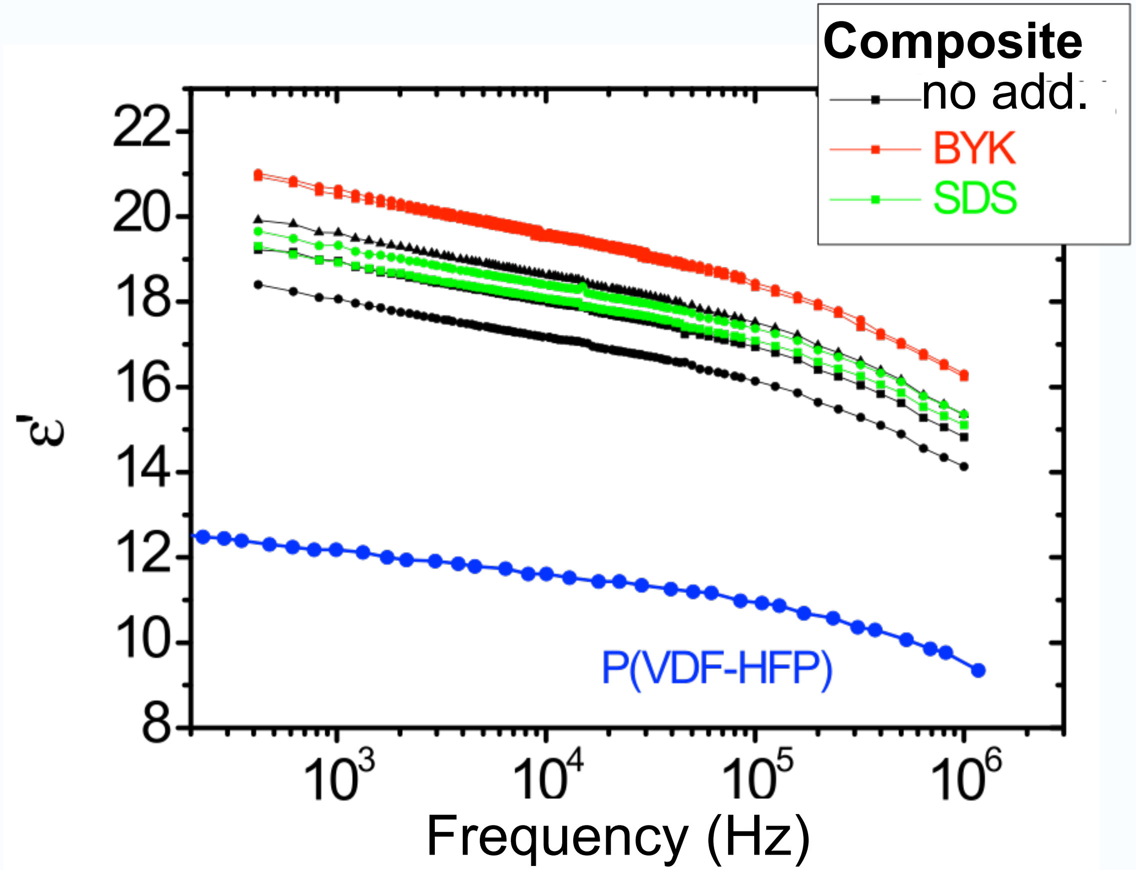
Simple models

- Serial or parallel connections
- Isotropic statistic distribution of spherical particles in a homogeneous matrix



ε_r Matrix ε_r Nanoparticle

→ Permittivität of the composite ε'

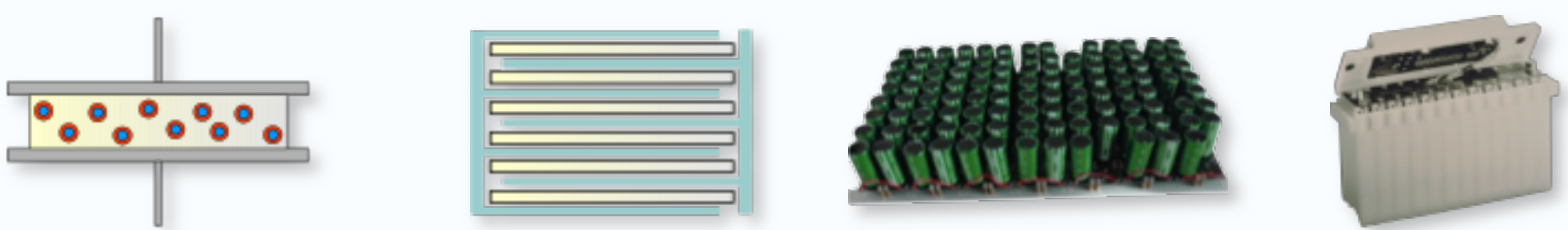


Permittivität ε' vs. frequency as a function of the structure of the 0–3 composite

Composite capacitors

Nanoparticles of ceramic dielectrics like $BaTiO_3$ ⇨ Specific surface coating ⇨ Embedding in polymer or glassy matrix | Processing to thin films and electric contacting

Single capacitor ⇨ Multilayer capacitor ⇨ Assembly ⇨ Module

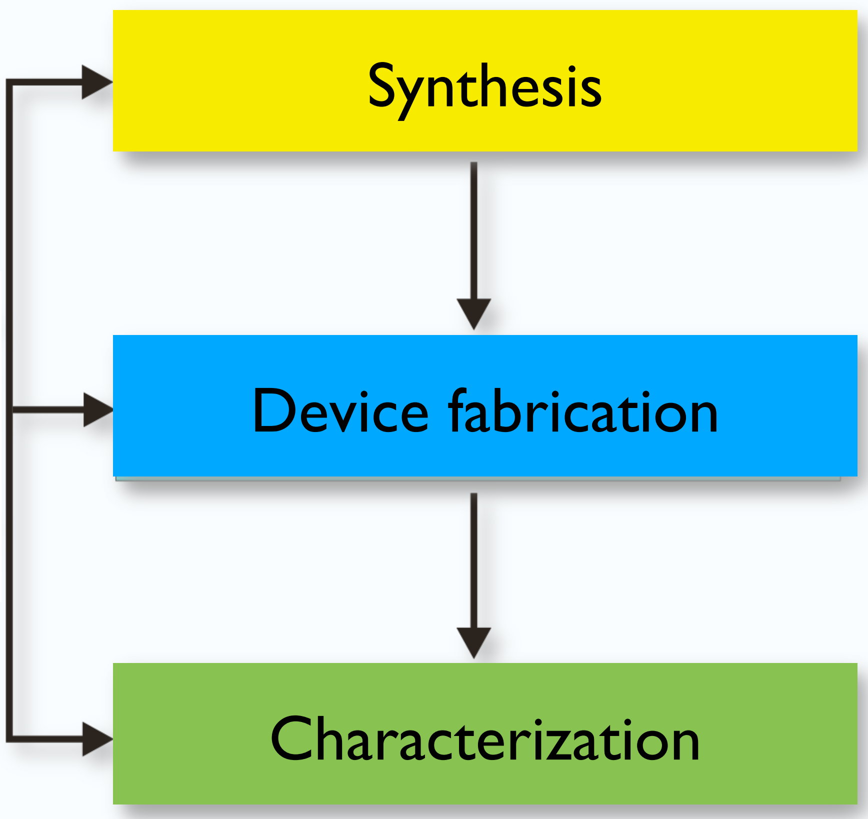


Advantages of composite supercapacitors

- Robust, negligible aging, high lifetime
- High charging voltages
- Thermal stability (operation temperatures > 60 °C possible
- No cooling
- High charging or discharging rates
- High efficiency
- Modular structure
- Environmentally friendly
- Reasonable energy and power density

Super-Kon team

Super-Kon collaboration



Institut für Chemie

- Synthesis of oxides and coating
- Thin film preparation
- Sintering spin coating, spray coating

Interdisziplinäres Zentrum für Materialwissenschaften

- Elektrodes
- Device fabrication
- Structure characterization

Institut für Physik

- Electric/dielectric characterization
- Theory/simulation

Device performance – early lab stage

Polymer composites

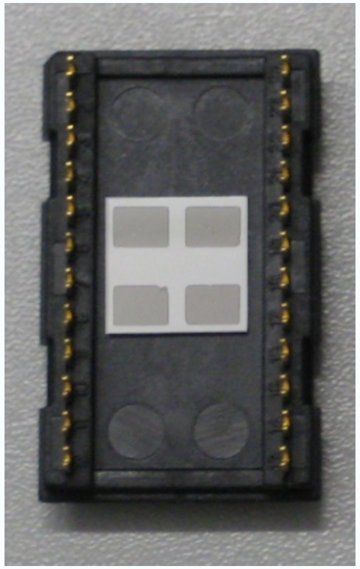
- $BaTiO_3$ ananoparticles
- Matrix: P(VDF-HFP)
- max. permittivity (1 kHz): 50
- max. field strength: 100 V/µm
- Energy density ~ 10 J cm^{-3}

Glassy composites

- $Ba(Ti,Ge)O_3$ nanoparticles
- Matrix: BBS glass
- max. permittivity (1 kHz): 4000
- max. field strength: 6 V/µm
- Energy density ≈ 1 J cm^{-3}

- Electrodes investigated: Aluminium, Silber, Gold

Next targets of the Super-Kon project



- *Proof-of concept* →
  Development of a demonstrator module
- Analysis of the electrical break down; defect studies
  → increase of energy density
- Testing in industrial environment
  - Influence of temperature, humidity, vibrations
  - Storage time, long-term stability
  - Compliance with industry standards
- Applications for energy harvesting

Technology roadmap