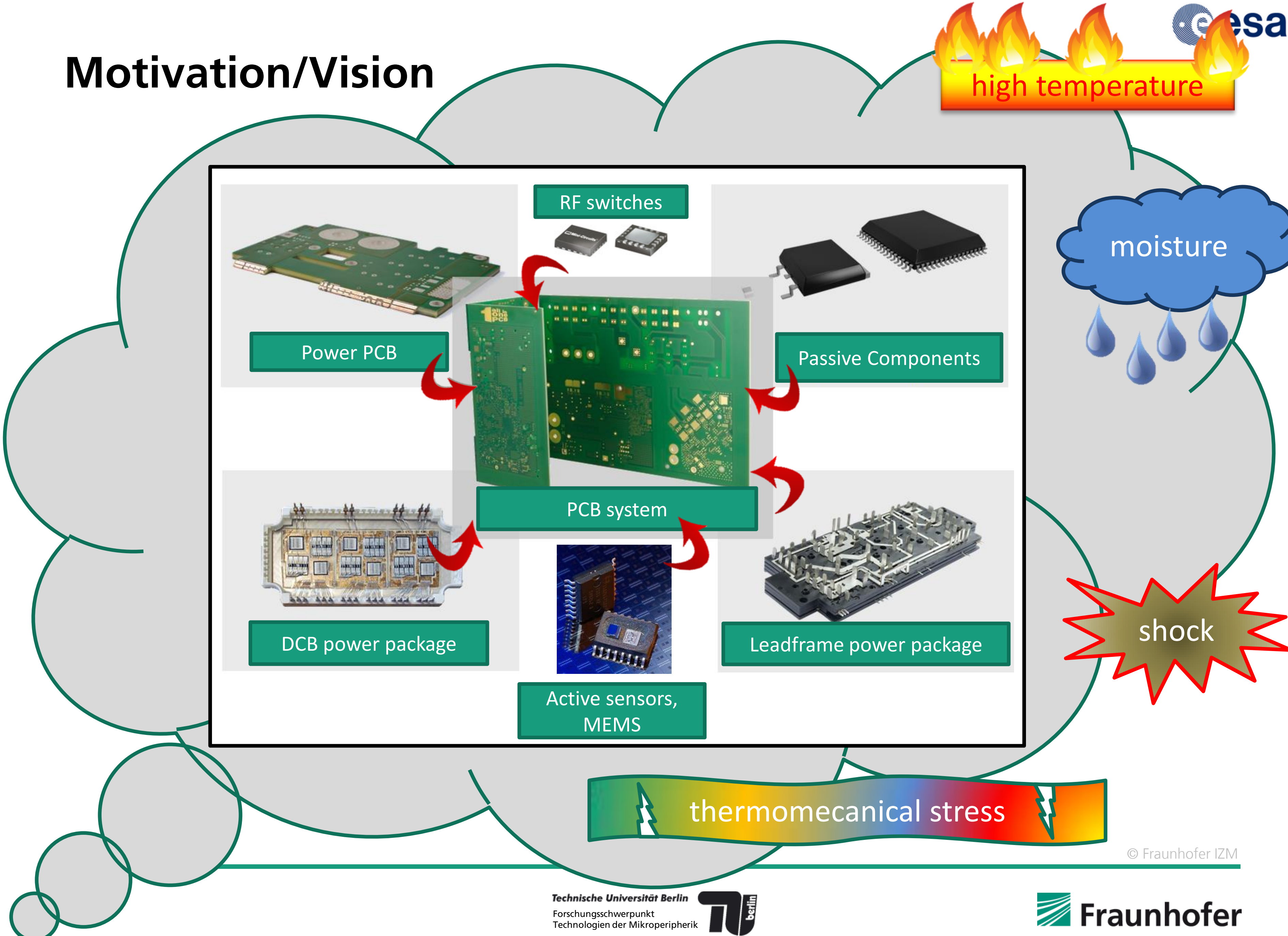
Micro electronic packaging concepts for small system integration and harsh environment

9th ESA ROUND TABLE ON MICRO AND NANO TECHNOLOGIES FOR SPACE APPLICATIONS

Name: Stefan Schmitz
Tel.: +49 30 46403-7906
E-Mail: stefan.schmitz@izm.fraunhofer.de

Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

Motivation/Vision



esa

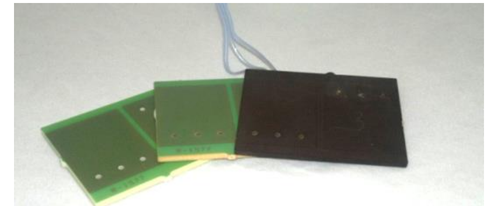
HELP – „Reliable and cost reduced High temperature ELectronic for electromobility applications using PCBs with high temperature suited polymer materials“

Focus of the project:

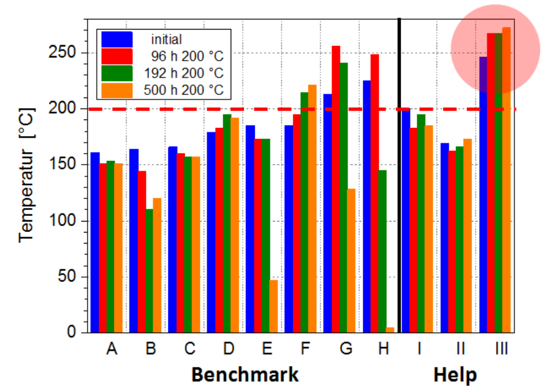
- Application of organic substrate materials for converters or drivers of motor aggregates (partners SEAG, Conti, Bosch, Siemens…)

Objectives for PCB/encapsulation:

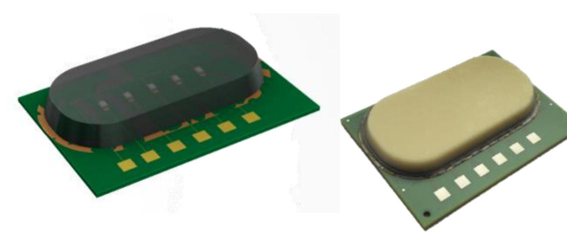
- Development of PCBs with a continuous operating temperature of 175°C (short time loads up to 220°C) and in parallel increase of temperature cycling capabilities at the higher temperature range
- Development and qualification of liquid and high temperature capable resins for encapsulation by FEM simulation and experimental approaches



Aged PCB samples – up to 500 h @ 250 °C



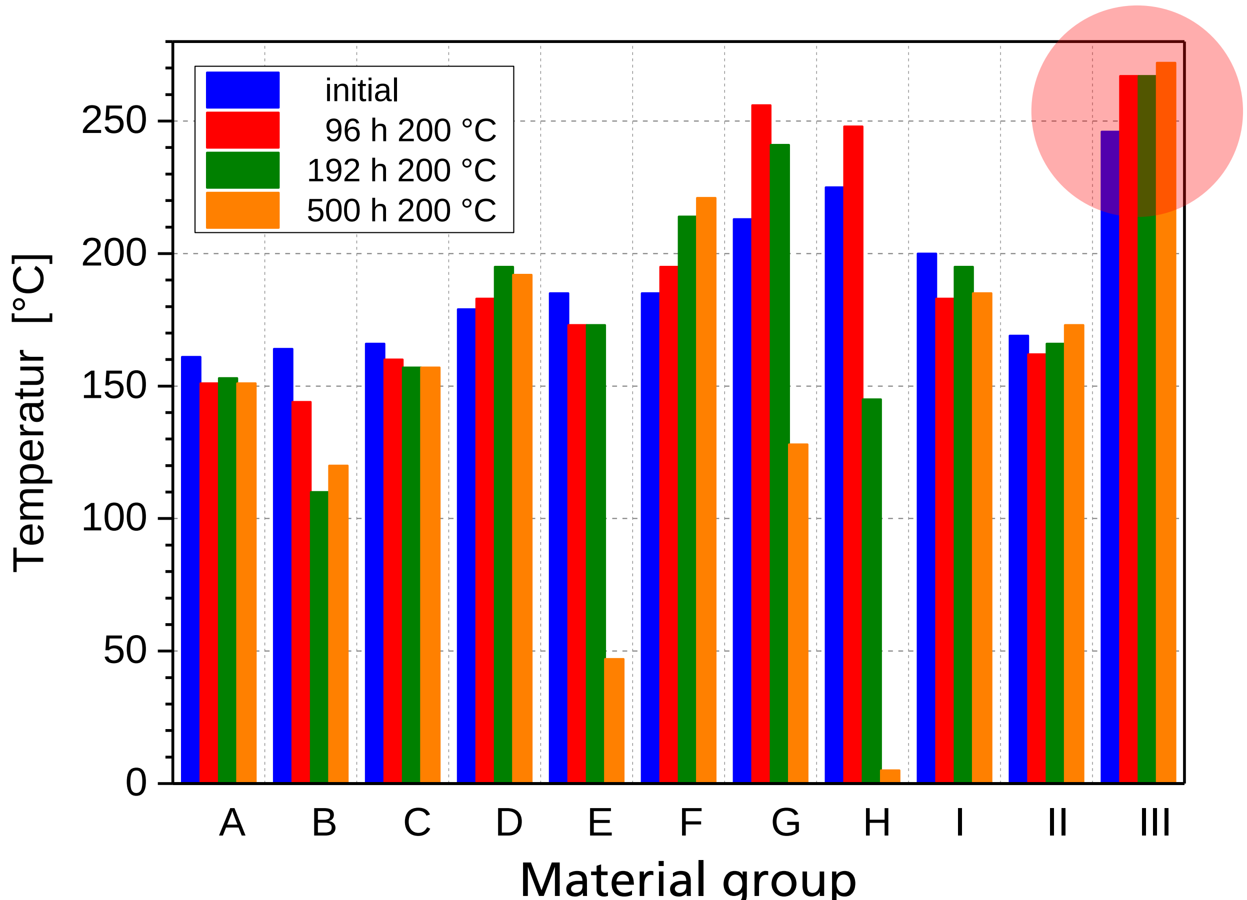
Measuring of PCB aging using Dielectric Spectroscopy (DEA)



Testing sample for material qualification and reliabiliy tests

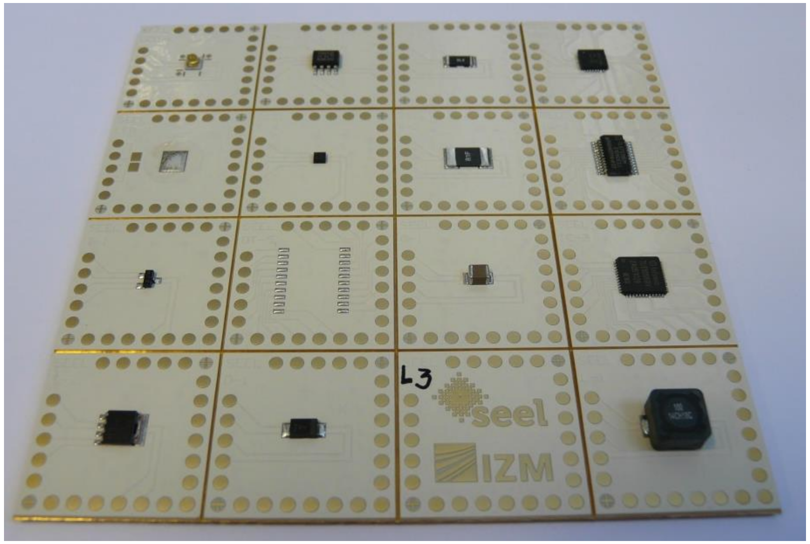
Karl-Friedrich Becker, Tanja Braun

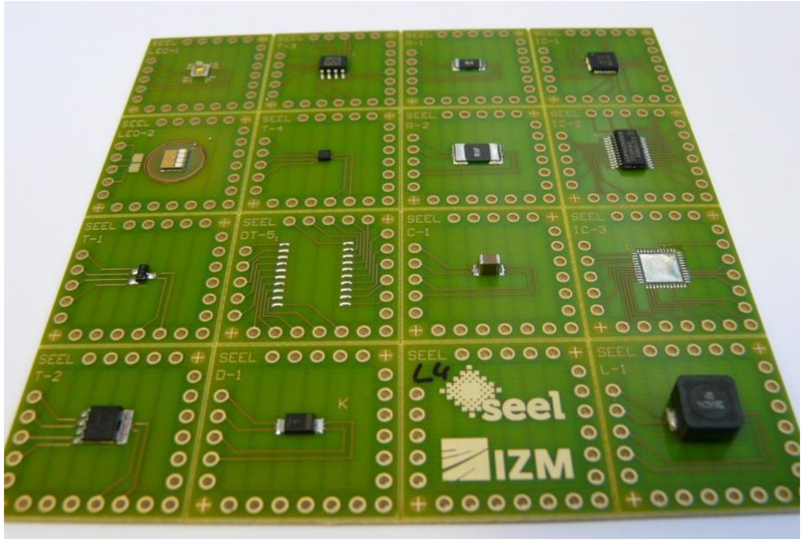
HELP – „Reliable and cost reduced High temperature ELectronic for electromobility applications using PCBs with high temperature suited polymer materials“



Karl-Friedrich Becker, Tanja Braun

High temperature interconnection technologies*



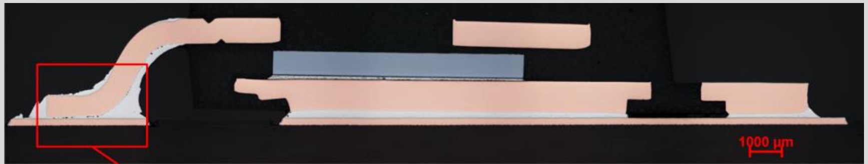


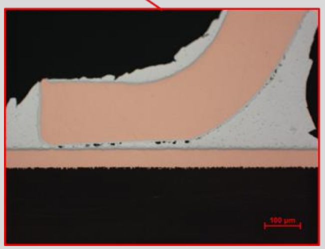
- FR4 and Cu-Metal-Core test boards
- Ag and Au metallization
- Interconnection technologies: Soldering, Ag Sintering, TLPS
- Temperature Cycle Testing: -55 °C to +175 °C

*BMBF funded sub-project of Seel

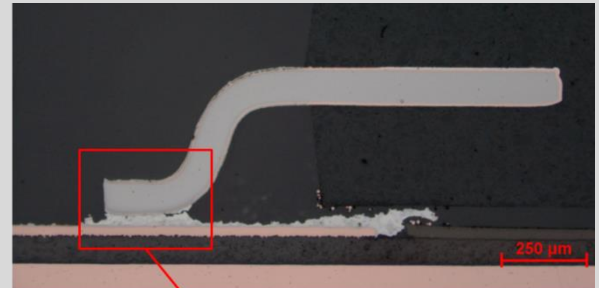
Dr. Matthias Hutter, Christian Ehrhardt

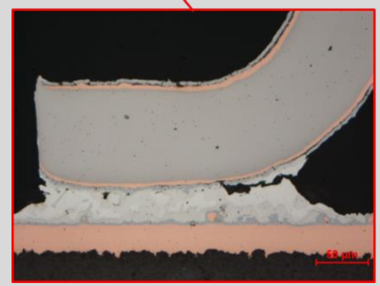
High temperature interconnection technologies



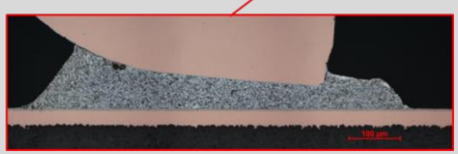


Soldering contacts survived 1000 cycles -55/175°C





TLPS* contacts survived 1000 cycles -55/175°C

Ag sintering (using pressure) contacts survived 1000 cycles -55/175°C

The most promising (in development) high temperature interconnection technology is the pressure-less sintering technology offering the highest operating temperatures.

*transient liquid phase soldering (diffusion soldering)

Dr. Matthias Hutter, Christian Ehrhardt

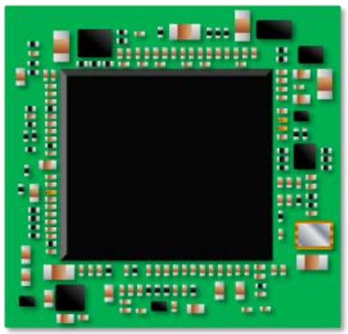
Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

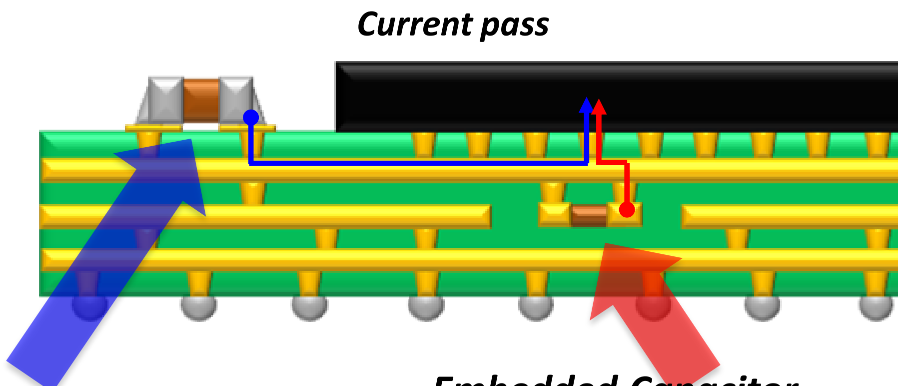
seel Solutions for Energy Efficient Lighting

Fraunhofer IZM

Motivation for Embedding of passive Components

- improved electrical performance
- high reliability
- cost saving

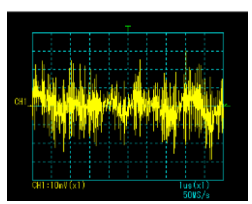




Surface mounted Capacitor

Surface mounted capacitor can't be mounted underneath LSI

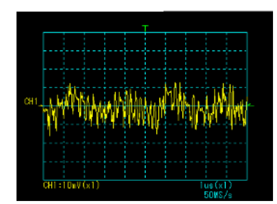
Low efficiency



Embedded Capacitor

Embedded capacitor can be mounted underneath of LSI

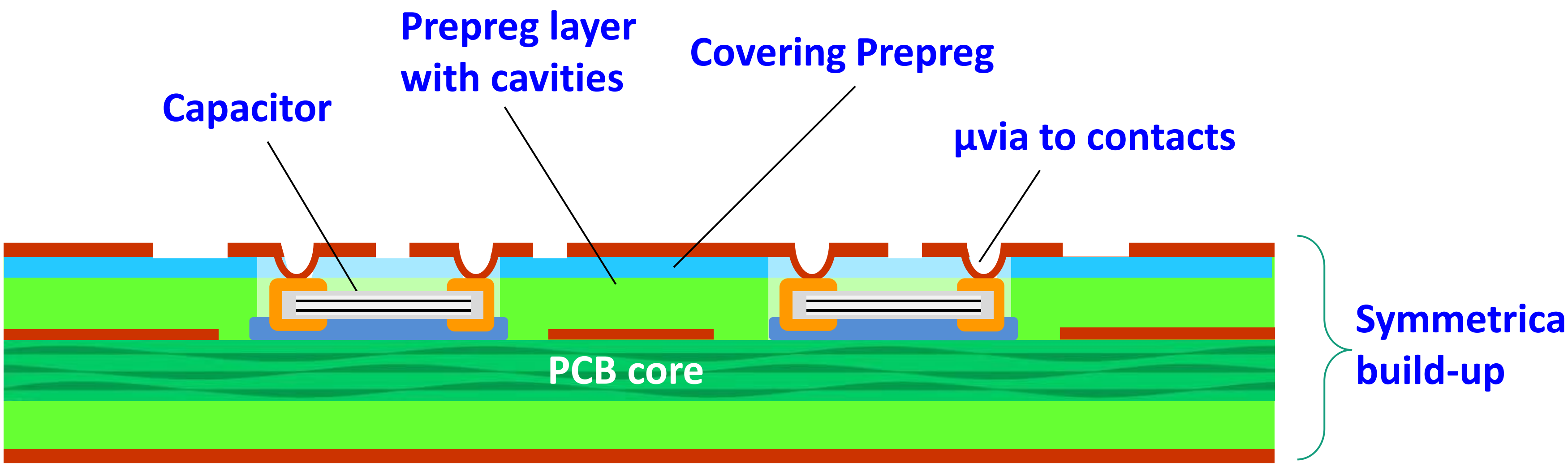
Noise suppression

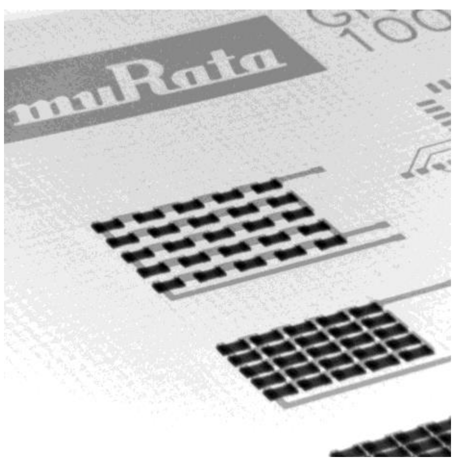


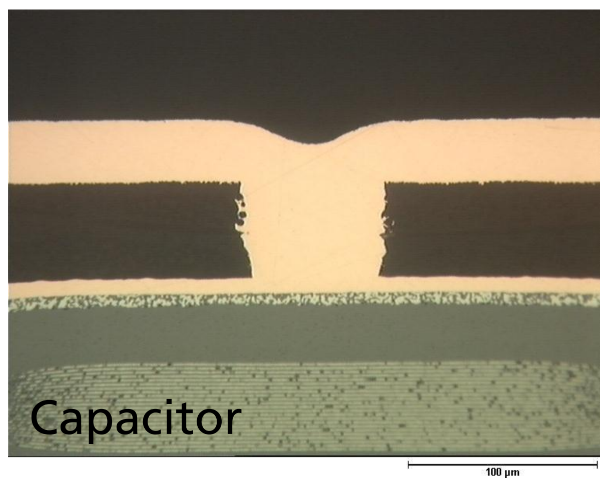
Embedded capacitor contributes to high performance of LSI.

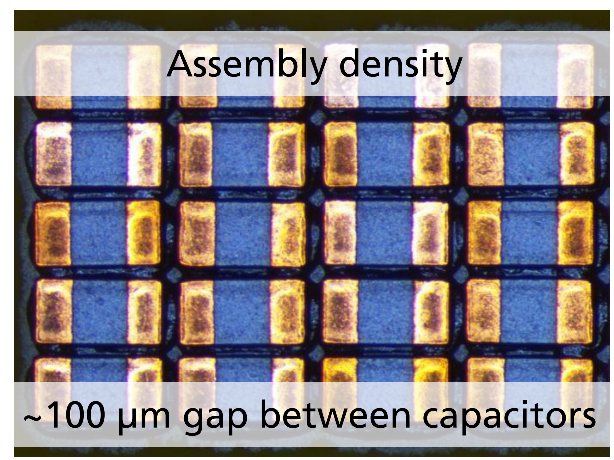
Embedding Concept

- Thin cap into a build up layer and electrical interconnection by µ-via.









Thomas Löher, Andreas Ostmann

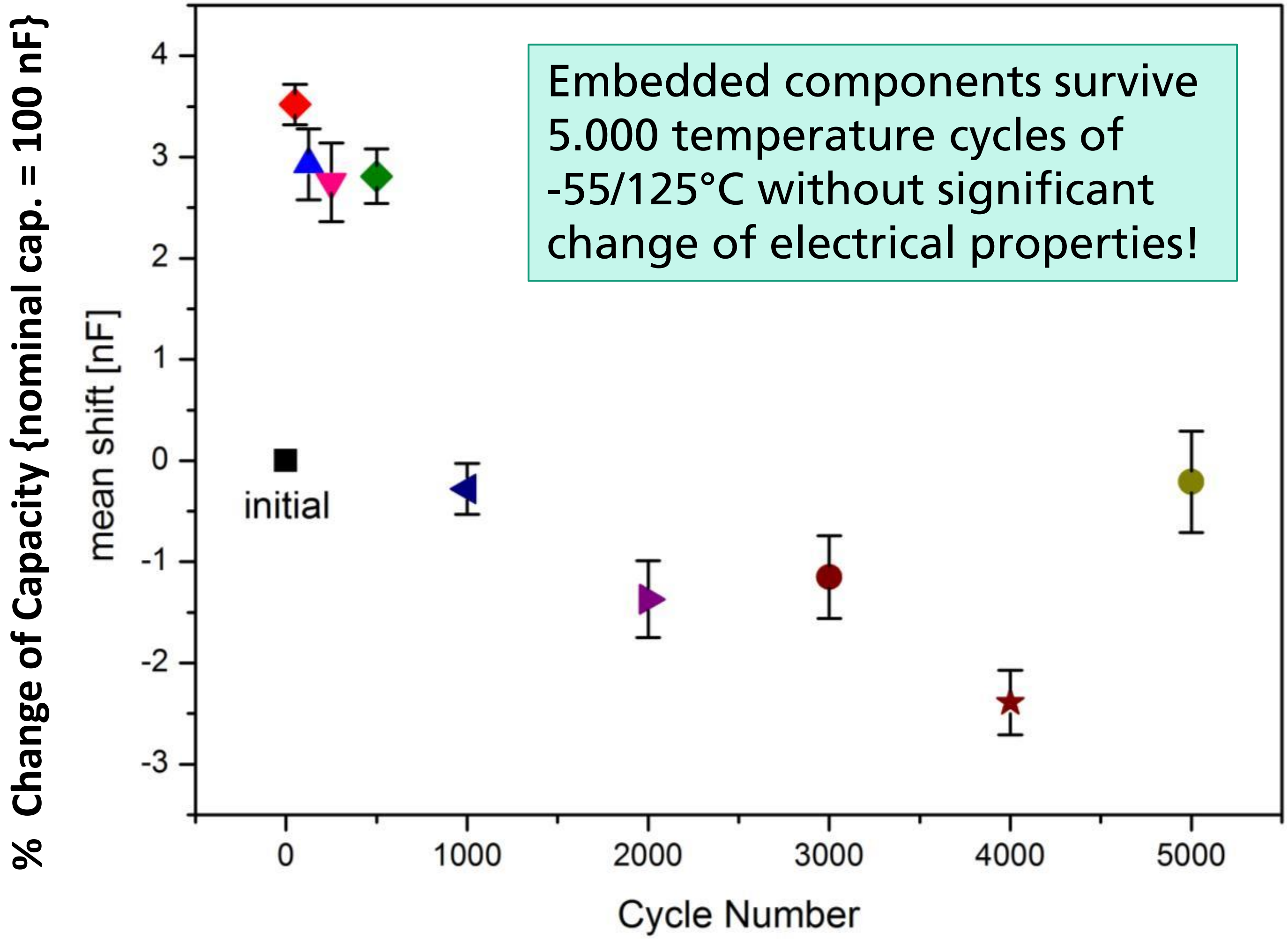
Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

muRata Innovator in Electronics

Fraunhofer IZM

Summary Temperature Cycling

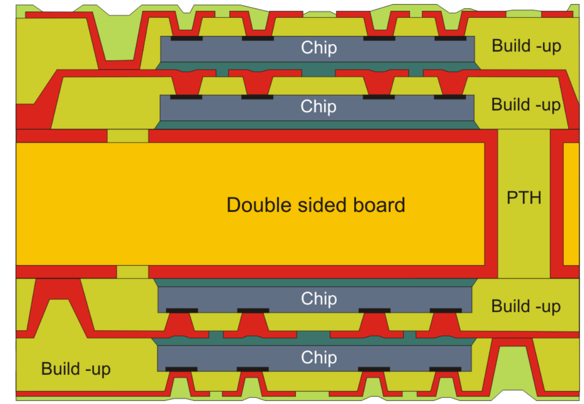
- 55 °C	-	25 °C	-	125 °C
10 min	-	5 min	-	10 min

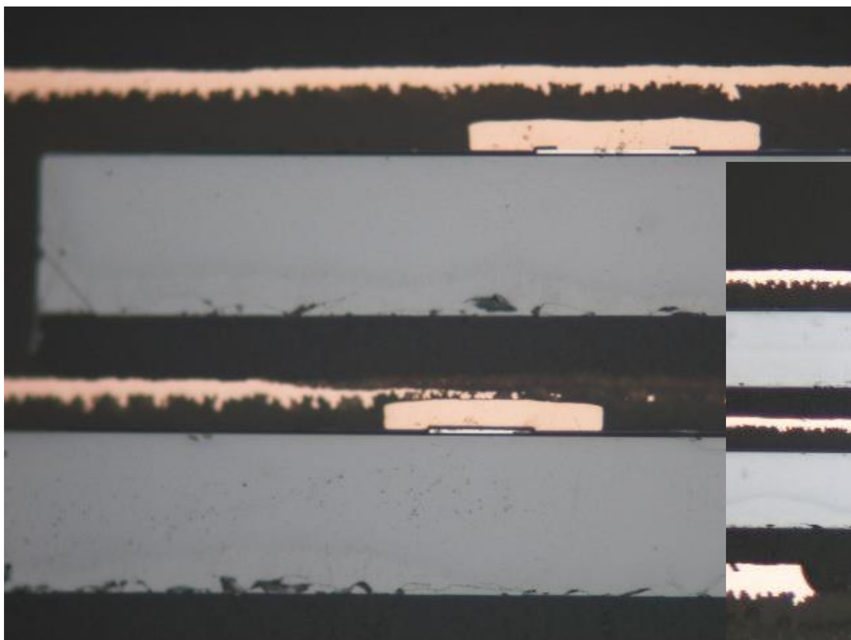


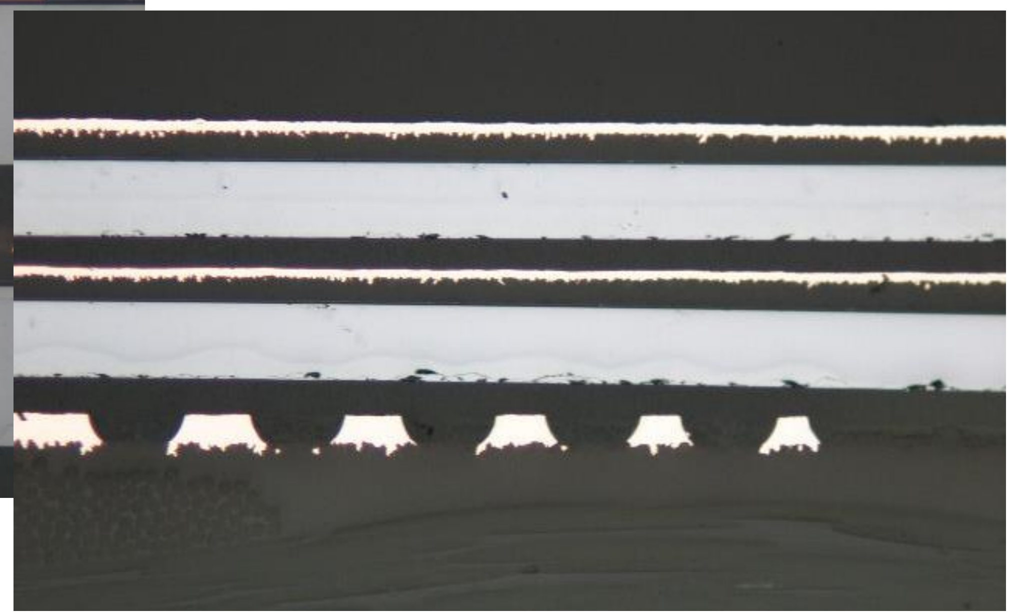
Thomas Löher, Andreas Ostmann

Embedding – next step → multiple active components

- Achievements
  - Physical embedding of two levels of chips
  - Identifying die bonding on structured copper as the critical step for multilevel embedding

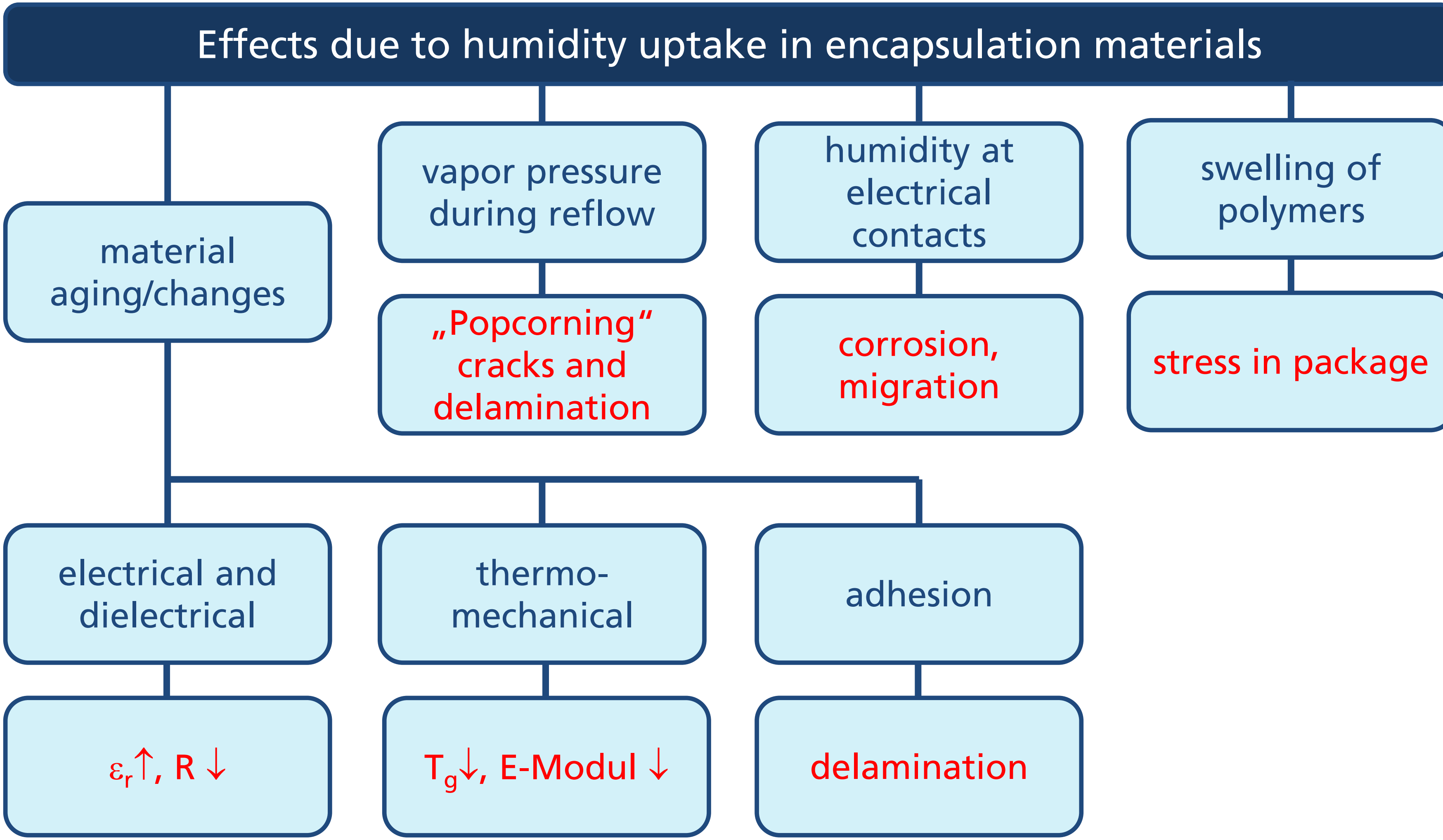






Thomas Löher, Andreas Ostmann

Reliability Influence of Humidity in Plastic Packages

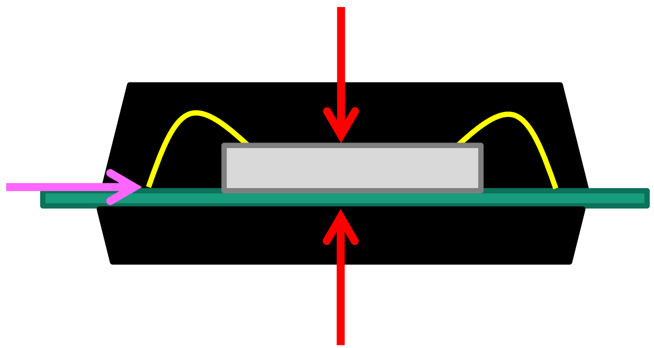


Dr. Tanja Braun, Dr. Hans Walter

Diffusion Paths into Plastic Packages

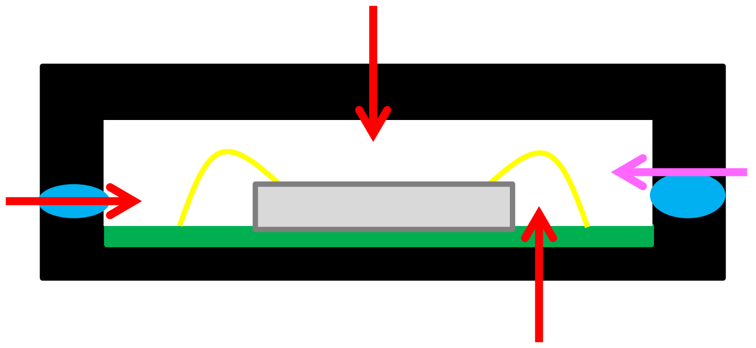
Diffusion paths into the package:

- Through bulk material
- Along interfaces



from literature:

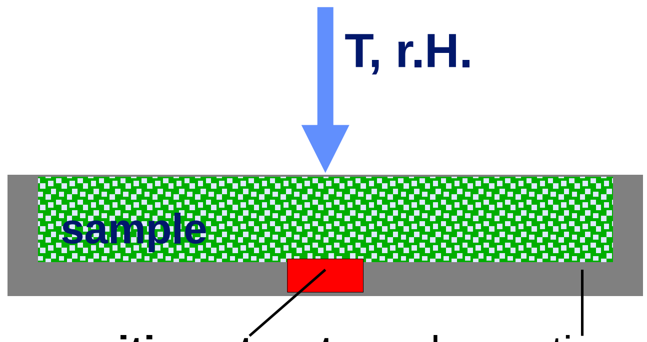
$D_{interface} > D_{bulk}$

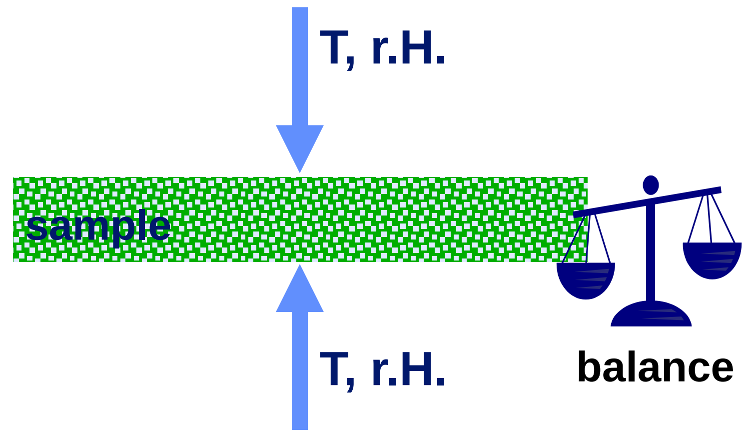


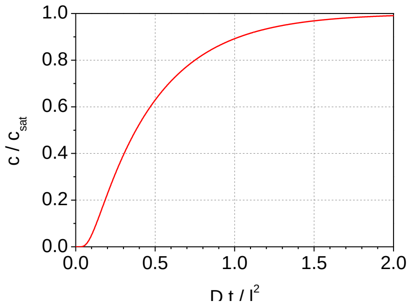
D_{bulk}: standard measurement procedure and equipment available

$D_{interface}$: no standard measurement procedure and equipment available

Measurement: Humidity Uptake and Diffusion

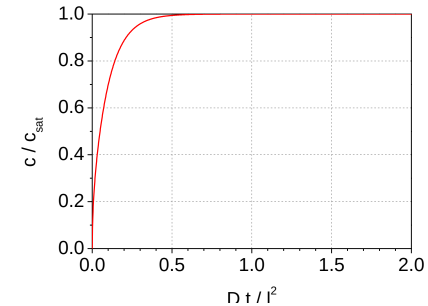






2nd Fick's law

$$\frac{\partial c}{\partial t} = D\frac{\partial^2 c}{\partial x^2}$$



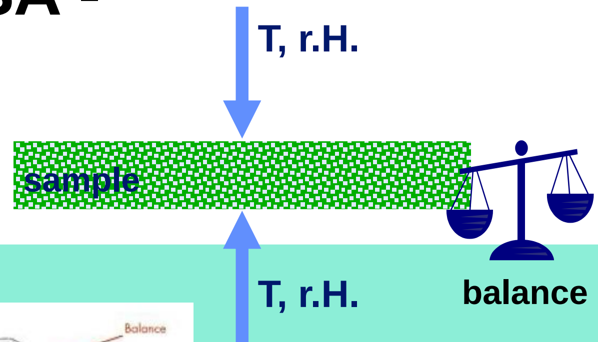
1-side diffusion

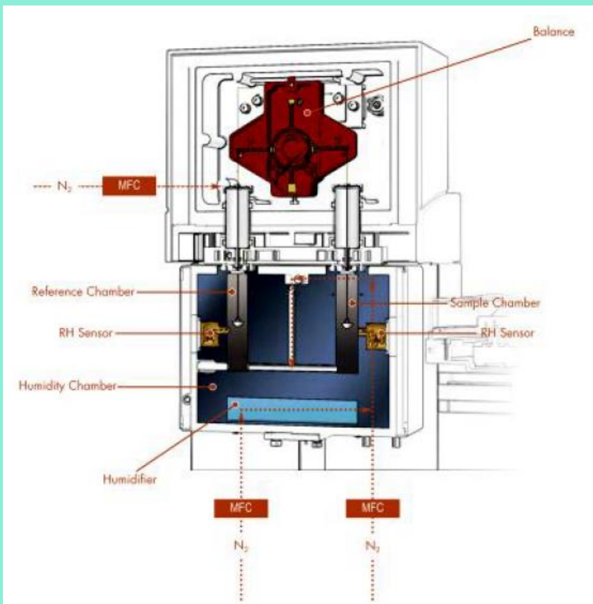
$$\frac{c}{c_{sat}} = 1 - \frac{4}{\pi}\sum_{n=0}^{\infty}\frac{(-1)^n}{2n+1}\exp\left[-D\left((2n+1)\frac{\pi}{2l}\right)^2 t\right]$$

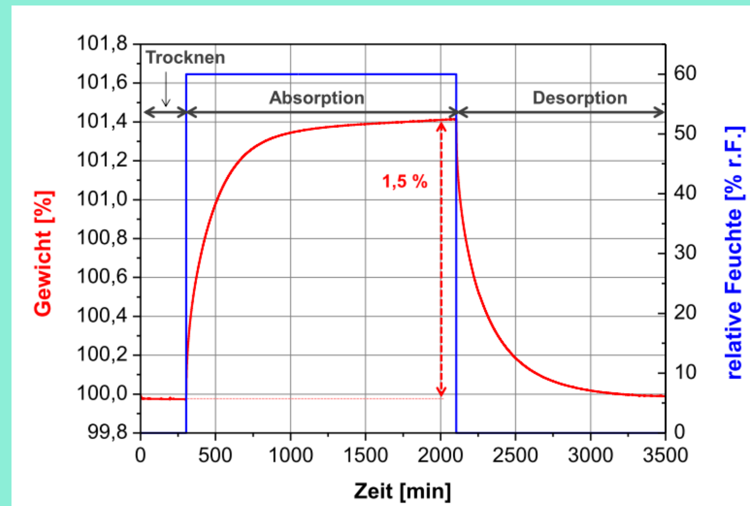
2-side diffusion

$$\frac{c}{c_{sat}} = 1 - \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-D\left((2n+1)\frac{\pi}{l}\right)^2 t\right]$$

2-sided Diffusion – Standard Test Method
- Sorption Analysis SA -

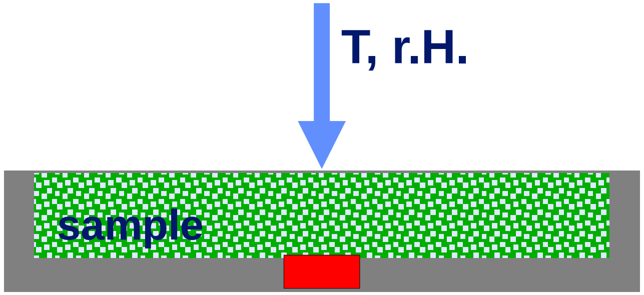




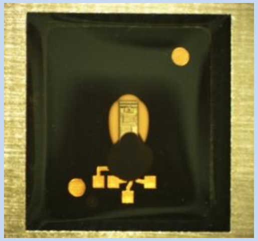


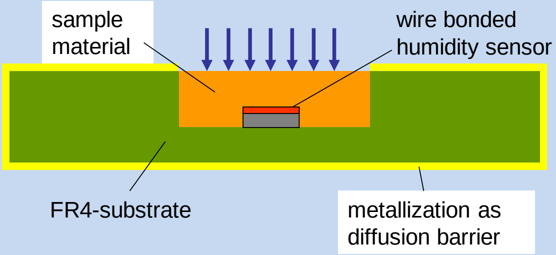
Gravimetric analysis of materials under defined environments (temperature/humidity)
insitu measurement of absorption and desorption

1-sided Diffusion – New Test Methods



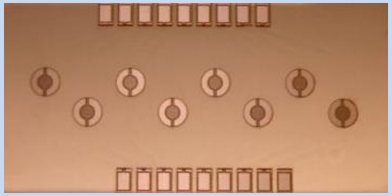
Packaged Humidity Sensor

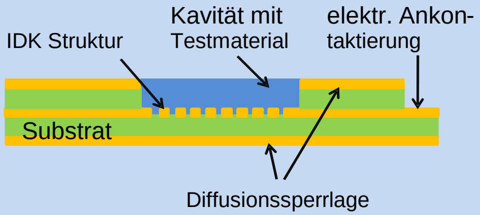




- Barrier layer above sensor made of sample material
- Storage of assembly under defined environment (temperature/humidity)
- Simultaneous online-measurement of different materials

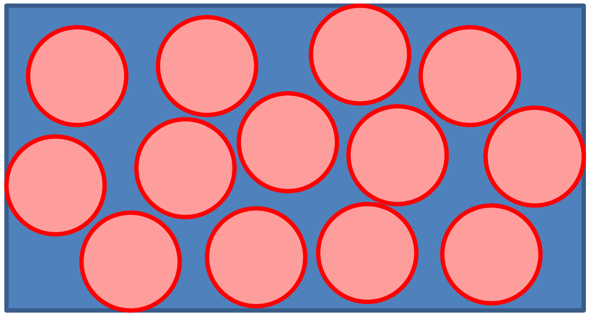
Dielectric Spectroscopy





- Sample material as encapsulation of comb electrodes
- Storage of assembly under defined environment (temperature/humidity)
- Simultaneous online-measurement of different materials at 1 Hz, 1 kHz, 1 MHz

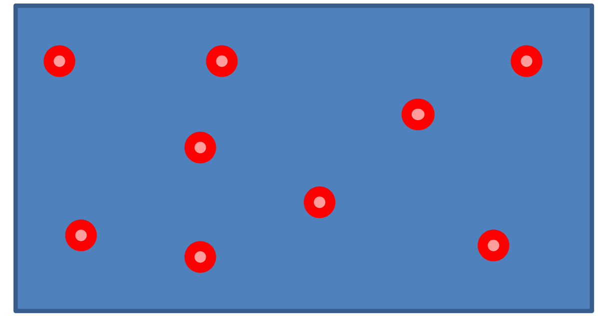
Influence of Filler Particles on Humidity Barrier Properties



High filler content [µm size]

⇒ Low water uptake

⇒ Diffusion path extension (tortuosity)



nm-sized filler

⇒ High surface impact due to high surface to weight ratio

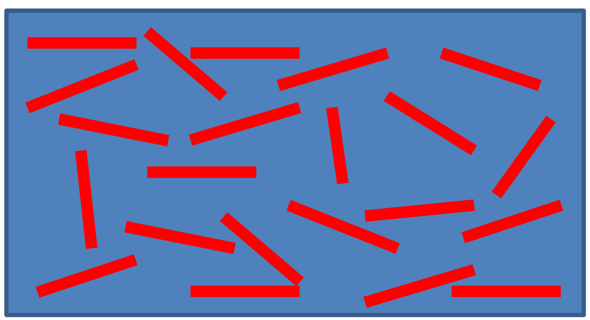
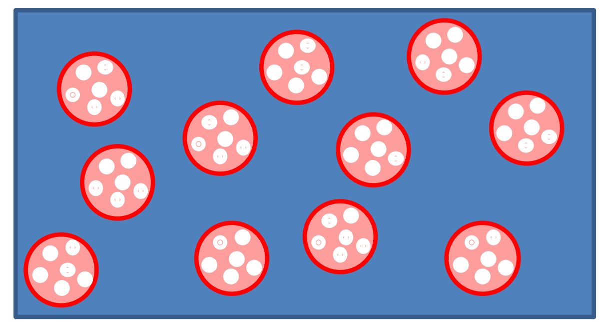


Plate-shaped fillers

⇒ Diffusion path extension due to layered structure (tortuosity)



Porous fillers

⇒ Catcher functionality

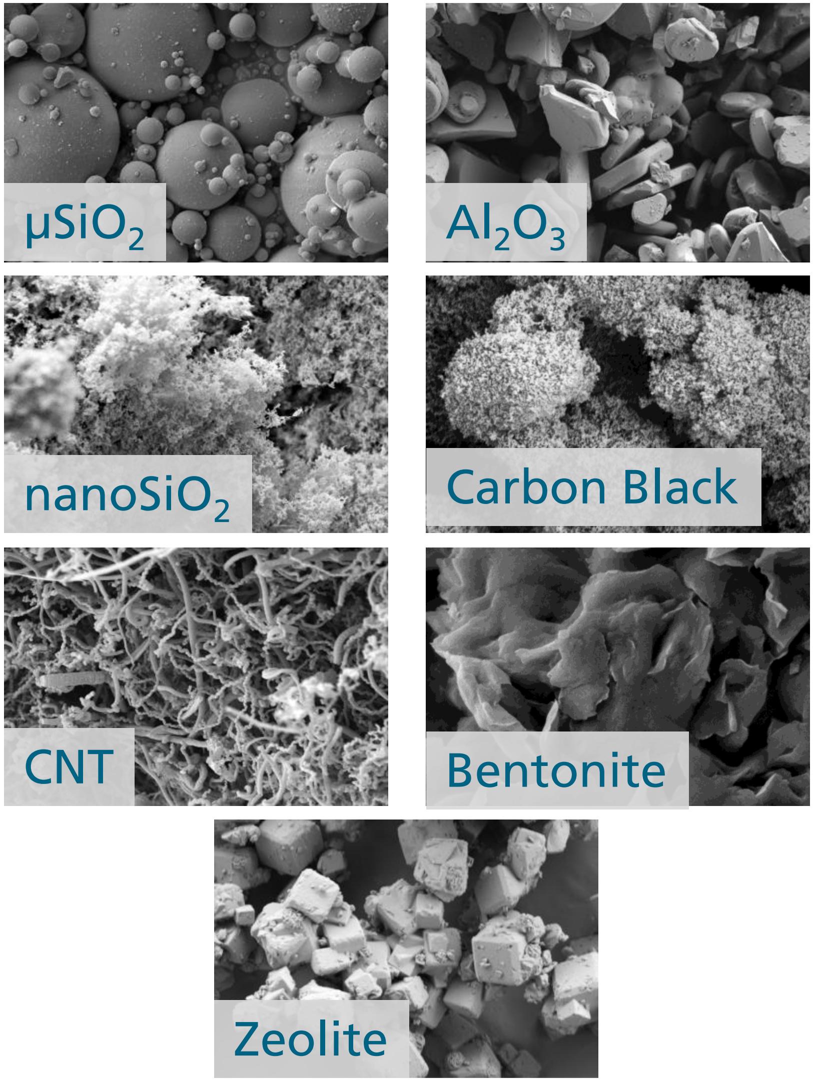
⇒ Higher water uptake

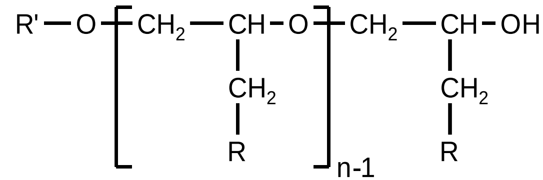
Dr. Tanja Braun, Dr. Hans Walter

Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

Fraunhofer IZM

Filler Particles Investigated





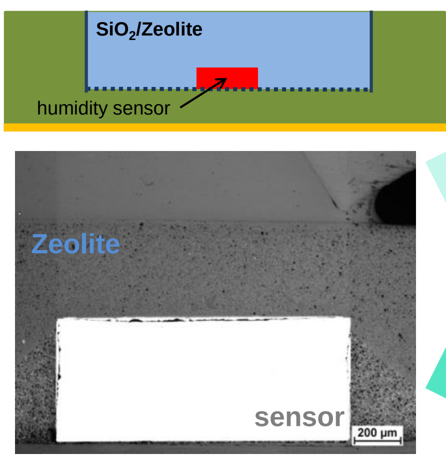
phenol hardened epoxy

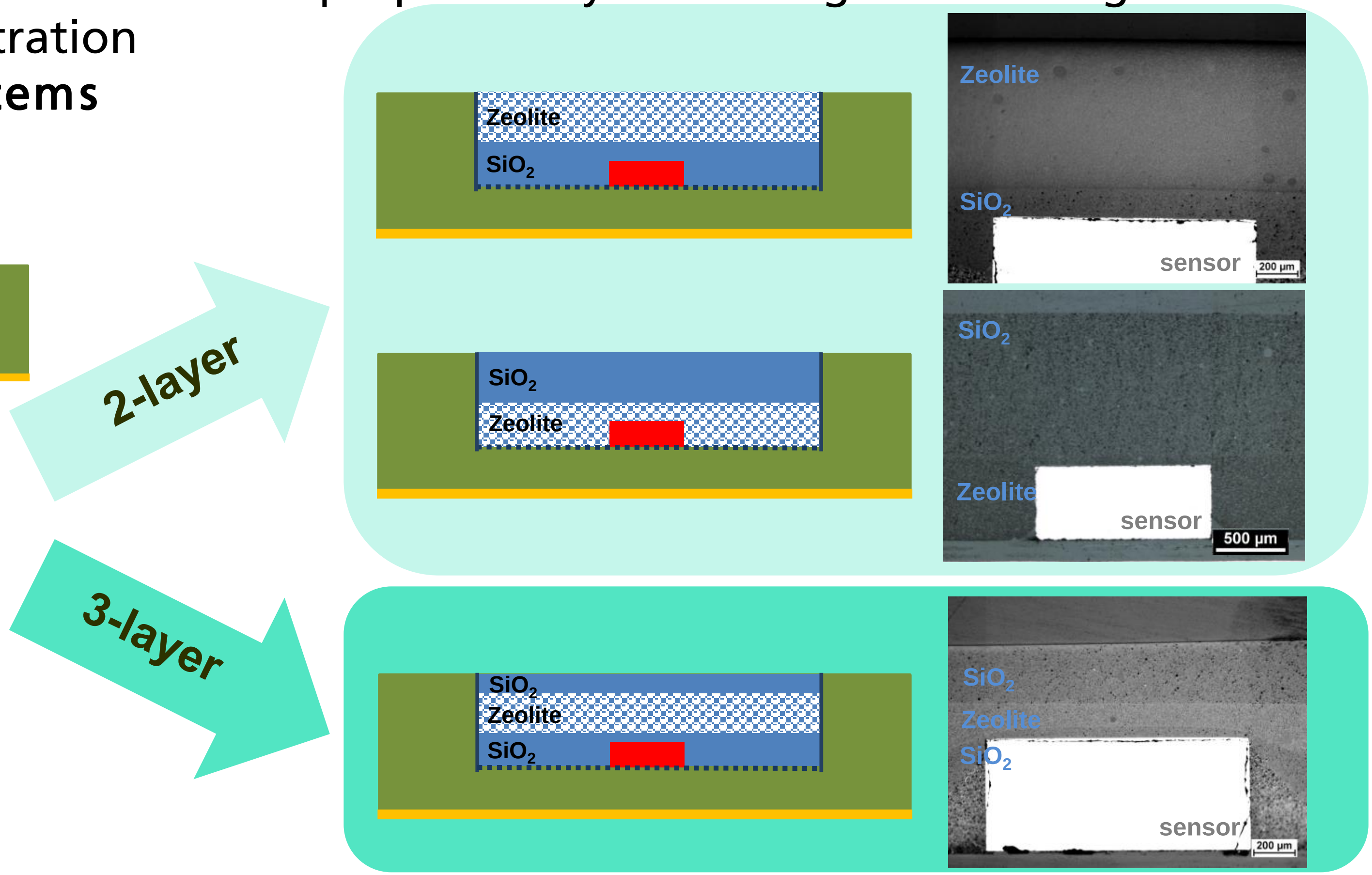
Filler type	Filler content [Weight-%]
none	0
µSiO_2	70
Al_2O_3	70
Zeolite (UOP-L/4A)	10
Zeolite (UOP-L/4A)	33
Zeolite (UOP-L/4A)	50
µSiO_2/UOP-L	40/20
nanoSiO_2	5
Bentonite (I.28E)	5
Carbon Black	5
CNT	5

Multi-Layer Systems

- Separation of mechanical/thermo-mechanical and humidity barrier functionality
- Enhancement of zeolite barrier properties by decreasing surrounding humidity concentration

➢ **Multi-layer systems**





Single-sided Moisture Absorption of Multi-Layer Systems

Class 1 – low barrier properties

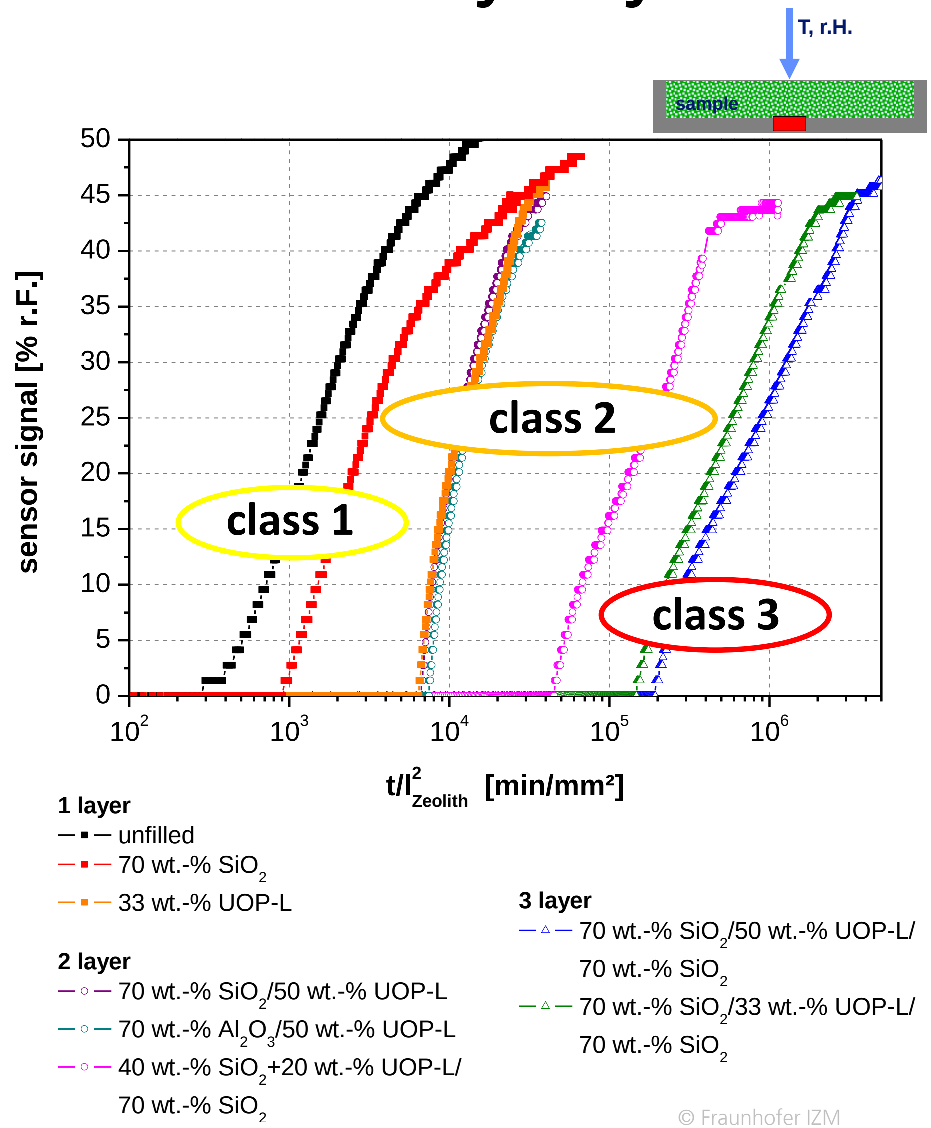
With these fillers only an improvement of four times compared to the unfilled resin can be achieved. Enhancement working principle seems to be the diffusion path extension for the systems with high filler content or water ad-or absorption at the filler particles itself.

Class 2 – enhanced barrier properties

Enhanced barrier properties can be achieved using single or two layer systems where one layer contains zeolite. With these materials and material systems an increased threshold time of **around 40 times** can be achieved.

Class 3 – highest barrier properties

Highest barrier properties, i.e. **around 400 times** longer threshold is feasible with three layer systems with a zeolite containing layer in the middle.

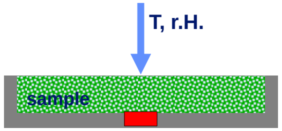


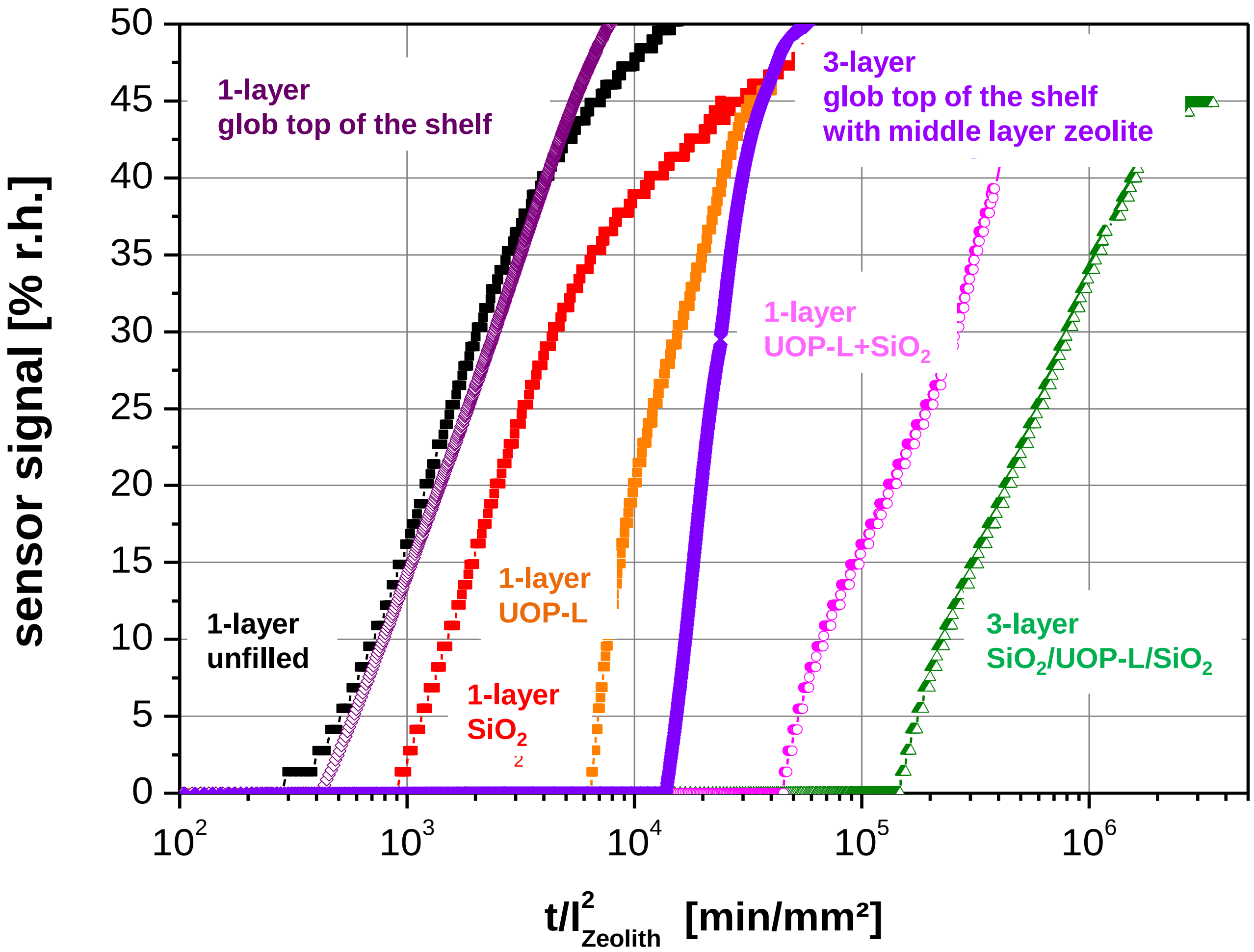
Dr. Tanja Braun, Dr. Hans Walter

Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

Fraunhofer IZM

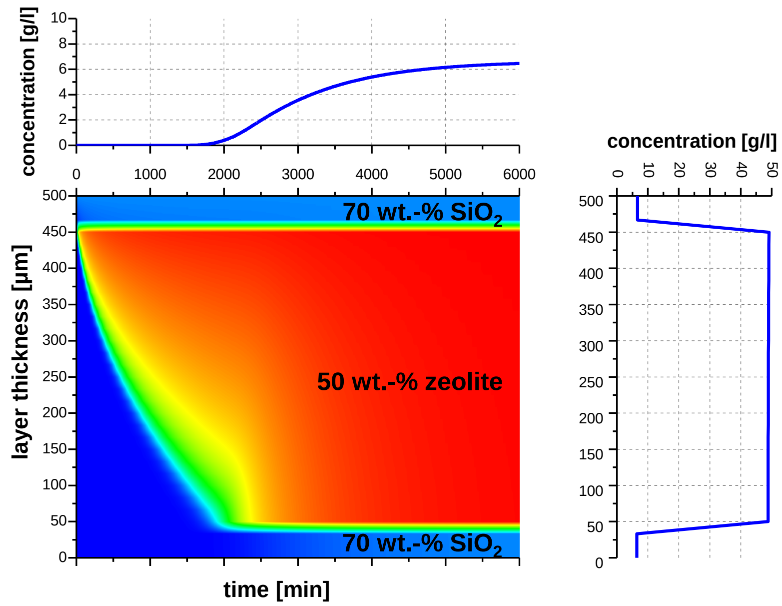
Application of Zeolite in Plastic Packages

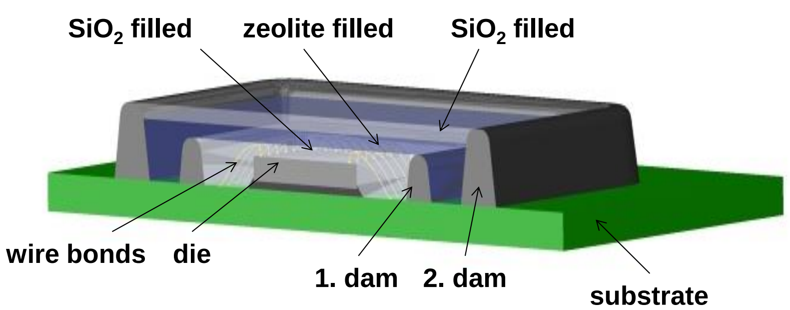




Application of Zeolite in Plastic Packages

- Measured material parameters allow the development of enhanced materials and encapsulations as well as the forecast of the humidity diffusion through these systems
- Adding zeolites to standard highly SiO_2 filled encapsulants would significantly increase the barrier properties of the encapsulant
- Use Case: multi-layer encapsulation including one covered zeolite layer e.g. for Chip-on-Board Dam&Fill encapsulation





Dr. Tanja Braun, Dr. Hans Walter

THANK YOU FOR YOUR ATTENTION!