KUNSTSTOFF TECHNIK LEOBEN

KONSTRUIEREN IN KUNST- UND VERBUNDSTOFFEN

Effiziente Modellierung von Leiterplatten

Martin Pletz

Lehrstuhl für Konstruieren in Kunst- und Verbundstoffen
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4A Technologietag 2018
28. 2. 2018

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MONTAN UNIVERSITÄT

Forschungsschwerpunkte

Lehrstuhl für Konstruieren in Kunst- und Verbundstoffen

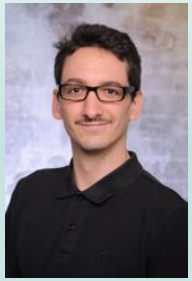
seit 2014

Univ. Prof. Clara Schuecker

Composite Simulation (CS)
(Endlosfaser, Sandwiches)

Mikromodelle
Multi-Skalen Ansätze
Kurzfaserverbunde

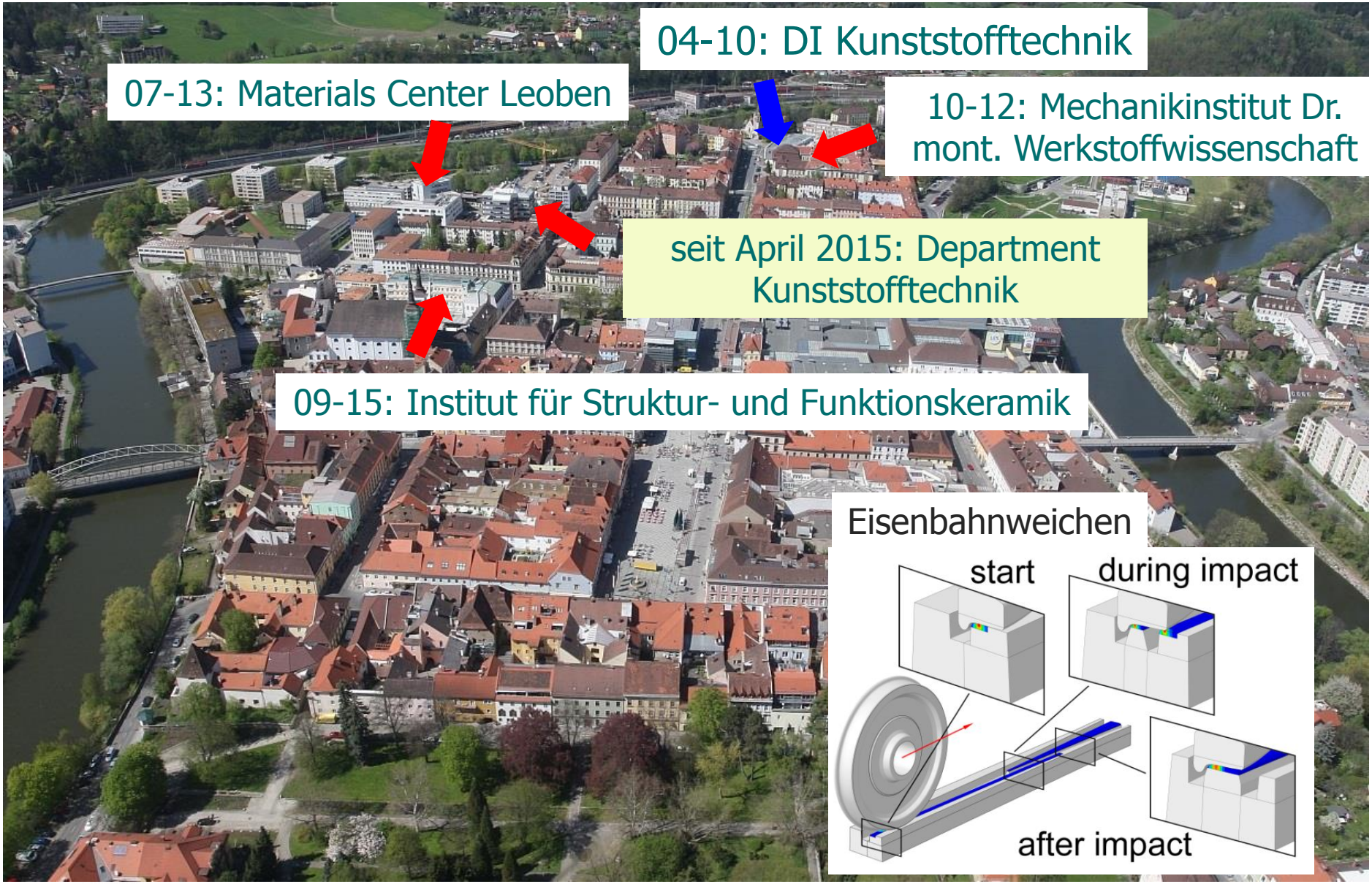
Dr.mont. Martin Pletz



Modellierung von Polymeren (MP)
(Materialverbunde, Kontakt)

seit 2015

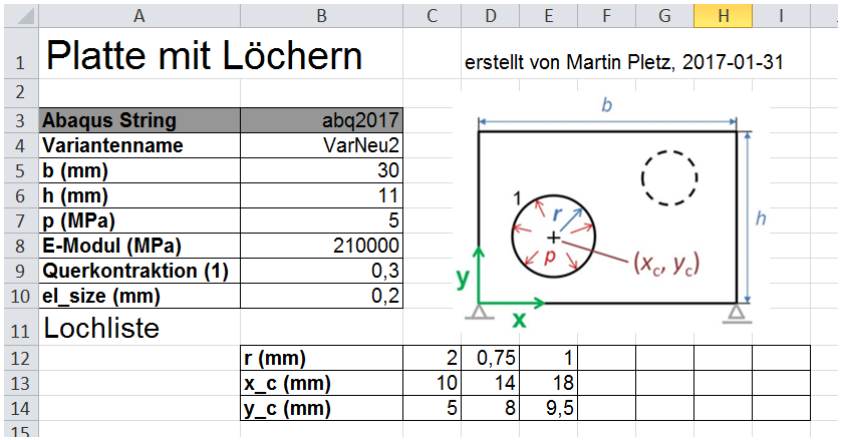
Dr. mont. Martin Pletz



Methodenbasiert, Tools, …

voll geskriptet – Von allen erwartet / allen beigebracht

aktuelle Methode der Wahl:
Abaqus & Python

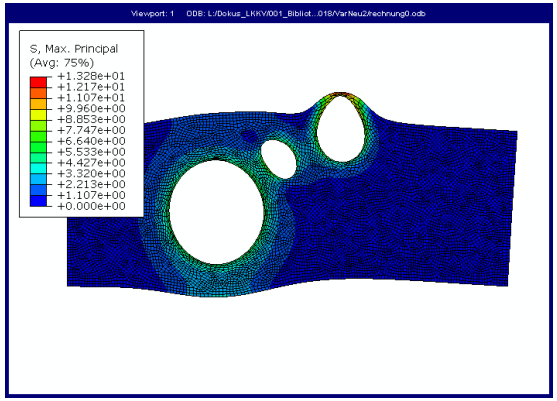


	A	B	C	D	E	F	G	H	I
1	Platte mit Löchern			erstellt von Martin Pletz, 2017-01-31					
2									
3	**Abaqus String**	abq2017							
4	**Variantenname**	VarNeu2							
5	**b (mm)**	30							
6	**h (mm)**	11							
7	**p (MPa)**	5							
8	**E-Modul (MPa)**	210000							
9	**Querkontraktion (1)**	0,3							
10	**el_size (mm)**	0,2							
11	Lochliste								
12		**r (mm)**	2	0,75	1				
13		**x_c (mm)**	10	14	18				
14		**y_c (mm)**	5	8	9,5				
15									

_angaben_modell.xlsx

Python, Abaqus

rechnung_s_field.dat
rechnung_u_field.dat

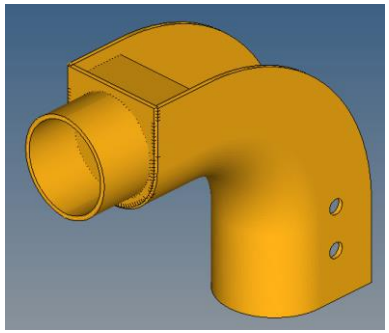


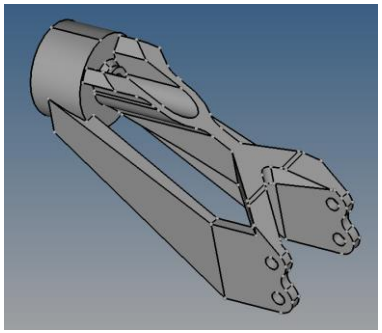
Neuerungen in Lehrveranstaltungen

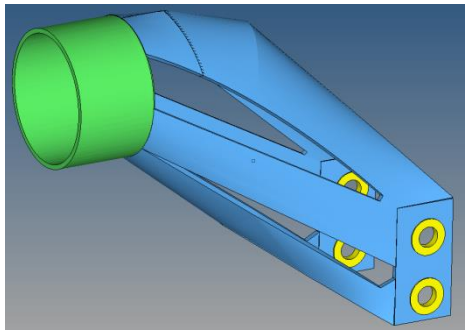
- Finite Elemente verpflichtend
- Wettbewerbe

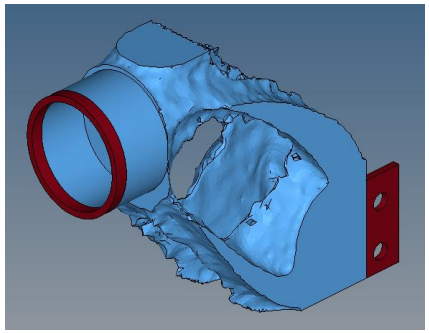
Pokale Konstruktionswettbewerb

Monitor- Halterung



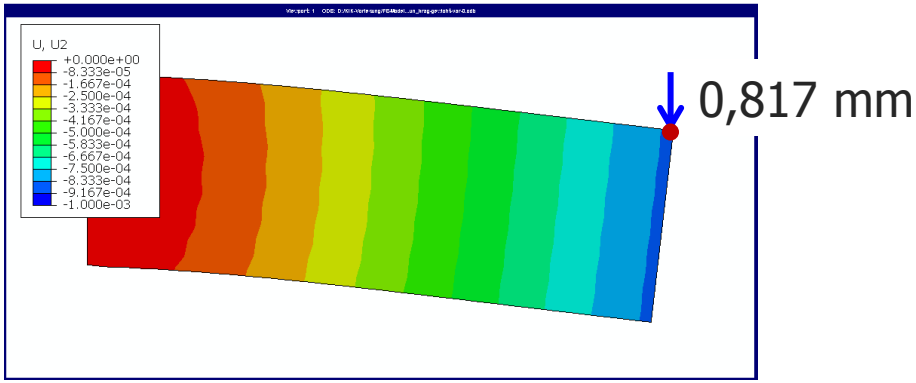






Das Problem: Kragträger – Eigengewicht

Vollquerschnitt:



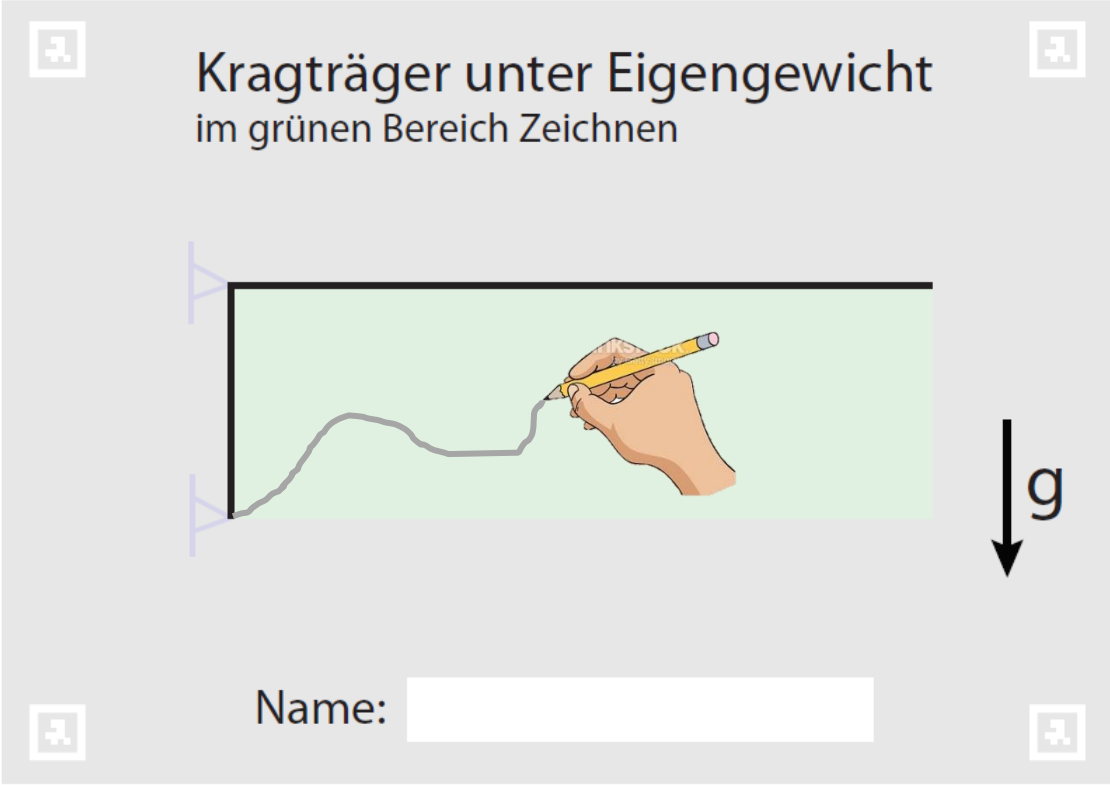
Gummi:
E-Modul: 2 MPa
Querkontraktion: 0,45
ρ = 1000 kg/m^3
g = 9,81 m/s^2

geht auch weniger Absenkung?

→ andere Geometrie

2D, ebene Dehnung

Zeichnen des Trägers



→ möglichst geringe Absenkung

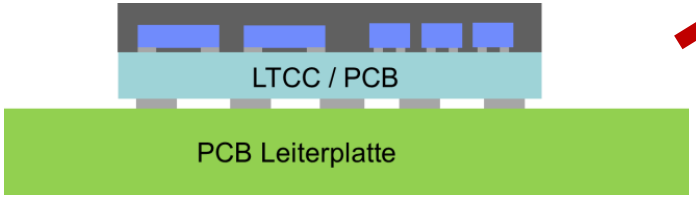
Voller Balken: 0,817 mm

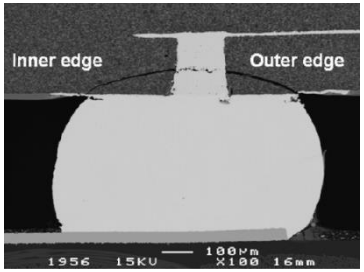
Zuverlässigkeit in der Mikroelektronik

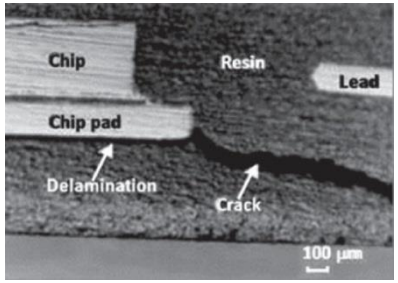
Tests mit ΔT oder mech. Belastung

Schädigung des Systems

Modul auf Leiterplatte: System



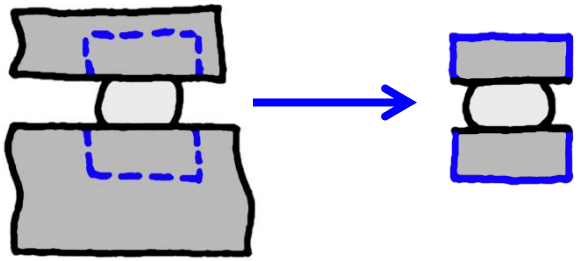




Kantenproblematik

3D Modell des Systems

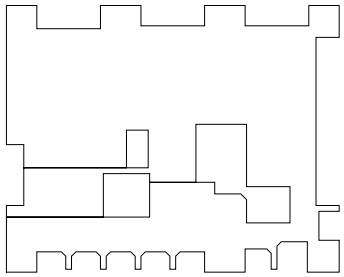
Lokale Schädigungsmodelle
Submodelle

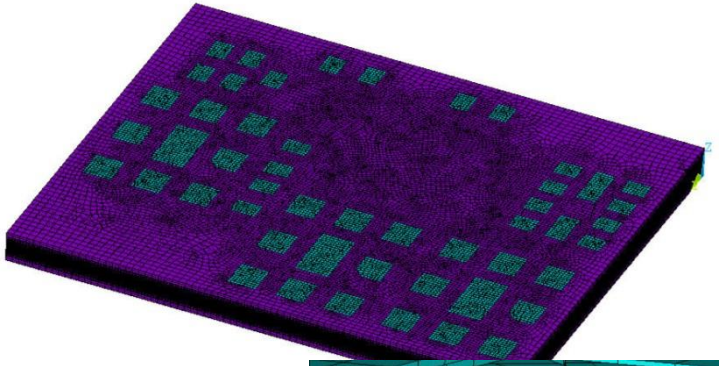


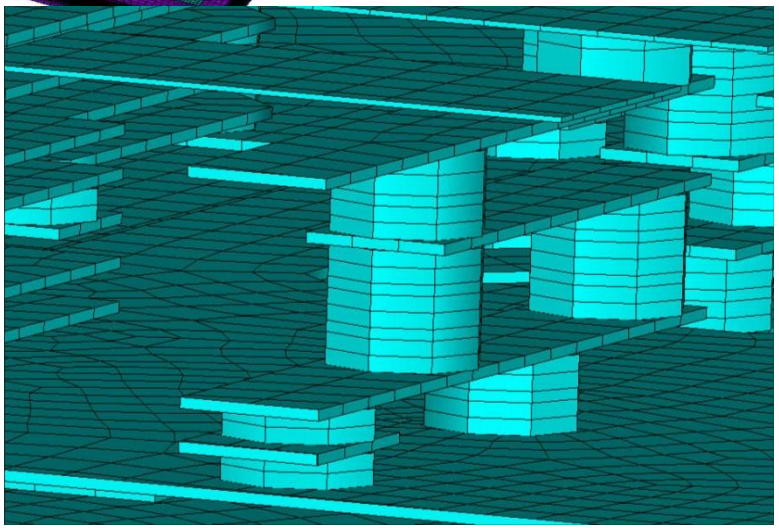
Geometrieaufbereitung

Übersetzungstool für GERBER Schichtdaten (2D)

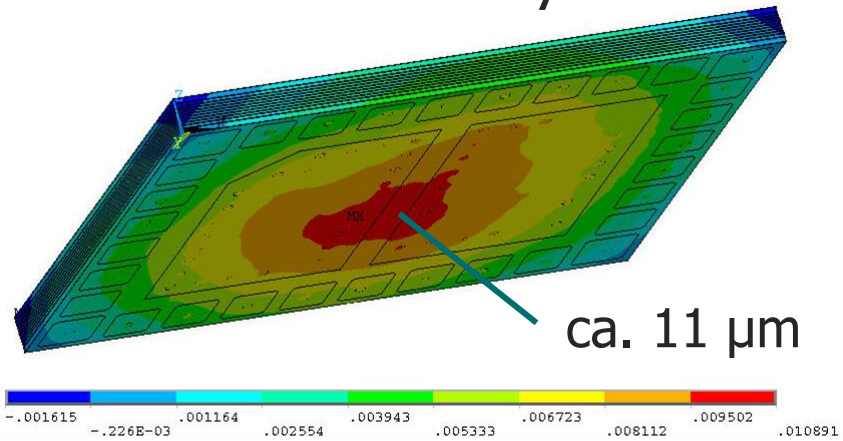
➔ in 3D FE Modell





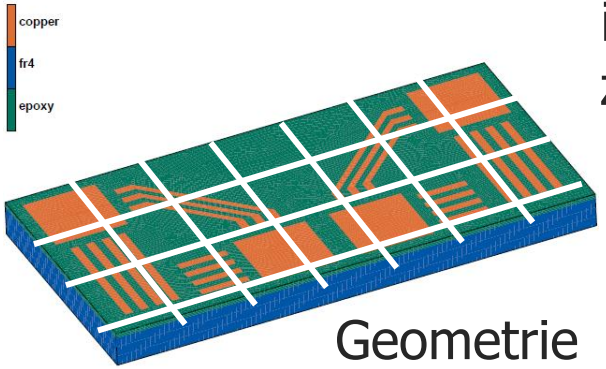


mechanische Analyse



Aufwölbung in mm

Homogenisierung



Geometrie

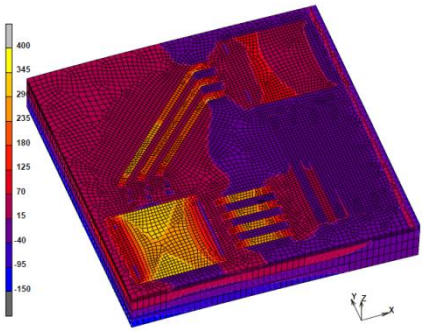
in Zellen zerlegen

Steifigkeiten (Elastizitätsmodul E)

orthotrop: $E_1 \neq E_2$

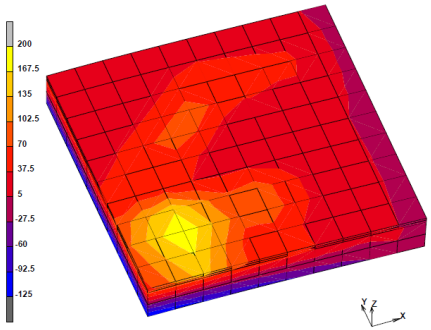
isotrop: $E_1 = E_2$

volles Modell



75 216 Elemente

homogenisiertes Modell



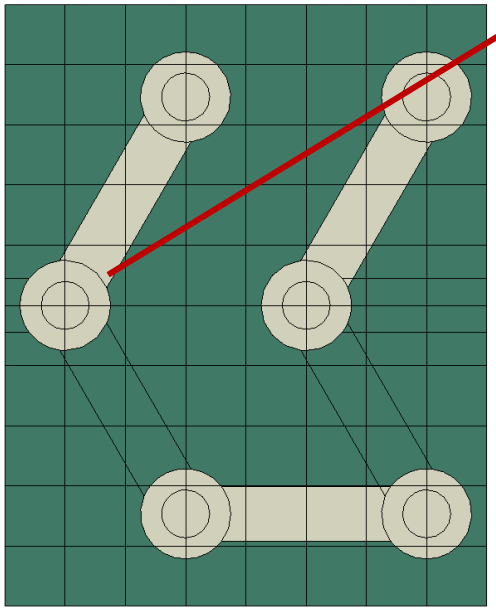
400 Elemente

➔ Verformungen berechenbar

R.L.J.M. Ubachs et al., Microelectronics Reliability, Volume 46, 2006.

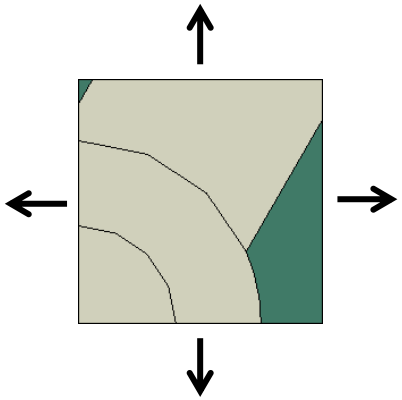
Homogenisierung im Detail

Aufteilen in Zellen



10 Unterteilungen

8 Unterteilungen



Steifigkeiten?
Wärmedehnungen?

lokale Eigenschaften ermitteln:

I. Voxel: ,

II. analytische Methoden

a) Serienschaltung

b) Parallelschaltung

$$E_p = \varphi_{met} E_{met} + (1 - \varphi_{met}) E_{Matrix}$$

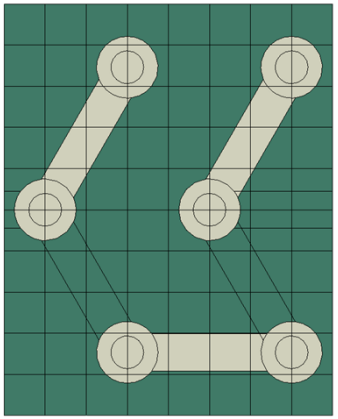
III. FE-Modell

a) periodische Randbedingungen

b) per. RBen + Planarität

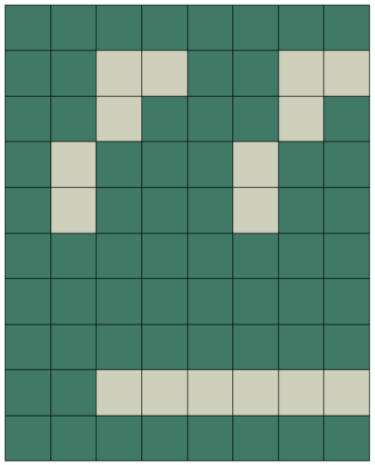
Eigenschaften der Zellen

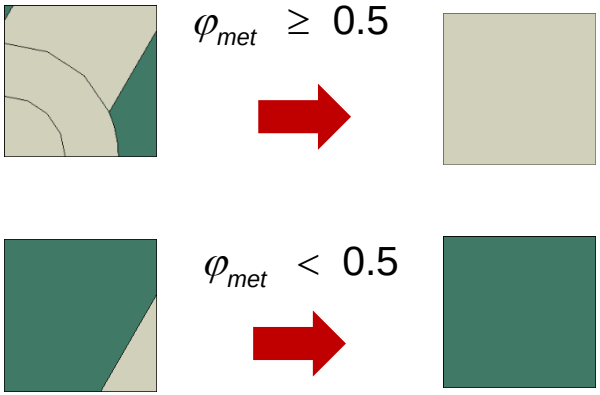
Aufteilen in Zellen



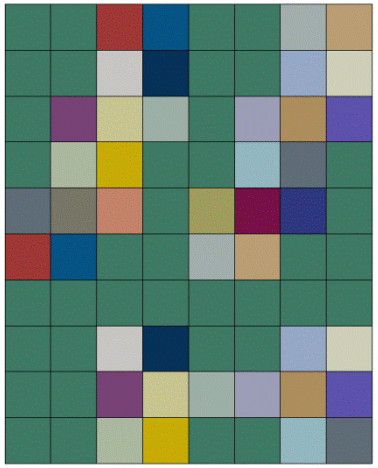
I) Voxel Modell

Volumenanteil Metall: φ_{met}





II) analytische Methoden



a) Serienschaltung (E-Modul E_s)

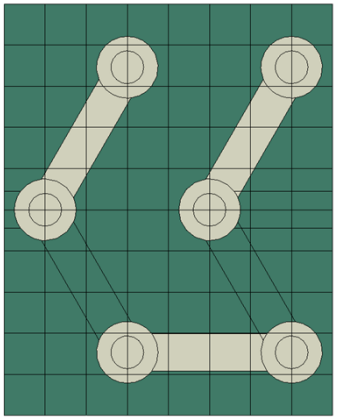
$$\frac{1}{E_s} = \frac{\varphi_{met}}{E_{met}} + \frac{(1-\varphi_{met})}{E_{Matrix}}$$

b) Parallelschaltung (E-Modul E_p)

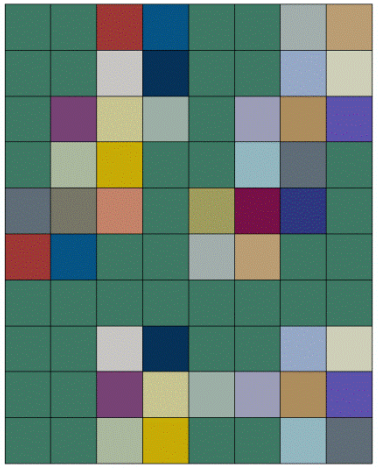
$$E_p = \varphi_{met} E_{met} + (1-\varphi_{met}) E_{Matrix}$$

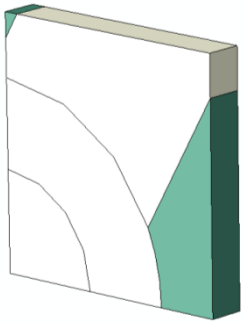
Eigenschaften der Zellen

Aufteilen in Zellen



III) FE Modell





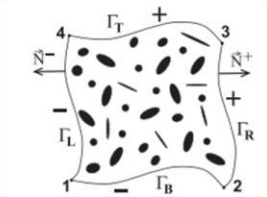
Aufbringen von:

- Dehnungen ε_{ij}
- Temperturänderung ΔT

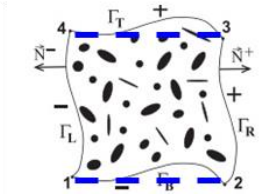
Aus σ_{ij}, ε_{ij}:

- Steifigkeitsmatrix $\boldsymbol{C}$
- Wärmedehnungen α_{ij}

a) periodische Randbedingungen



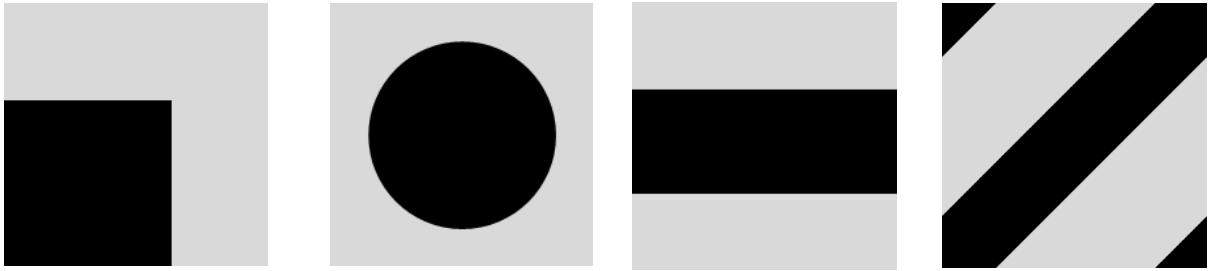
b) per. RBen + Planarität



$$\begin{bmatrix} \bar{\sigma}_{11} \\ \bar{\sigma}_{22} \\ \bar{\sigma}_{33} \\ \bar{\sigma}_{12} \\ \bar{\sigma}_{23} \\ \bar{\sigma}_{13} \end{bmatrix} = \begin{bmatrix} \bar{C}_{11} & \bar{C}_{12} & \bar{C}_{13} & \bar{C}_{14} & \bar{C}_{15} & \bar{C}_{16} \\ & \bar{C}_{22} & \bar{C}_{23} & \bar{C}_{24} & \bar{C}_{25} & \bar{C}_{26} \\ & & \bar{C}_{33} & \bar{C}_{34} & \bar{C}_{35} & \bar{C}_{36} \\ & & & \bar{C}_{44} & \bar{C}_{45} & \bar{C}_{46} \\ & symm. & & & \bar{C}_{55} & \bar{C}_{56} \\ & & & & & \bar{C}_{66} \end{bmatrix} \begin{bmatrix} \bar{\varepsilon}_{11} - \bar{\alpha}_{11}\Delta T \\ \bar{\varepsilon}_{22} - \bar{\alpha}_{22}\Delta T \\ \bar{\varepsilon}_{33} - \bar{\alpha}_{33}\Delta T \\ \bar{\varepsilon}_{12} - \bar{\alpha}_{12}\Delta T \\ \bar{\varepsilon}_{23} - \bar{\alpha}_{23}\Delta T \\ \bar{\varepsilon}_{13} - \bar{\alpha}_{13}\Delta T \end{bmatrix}$$

→ *effektive, anisotrope Eigenschaften*

Steifigkeiten von Zellen



Volumenanteil
Metall: 40%

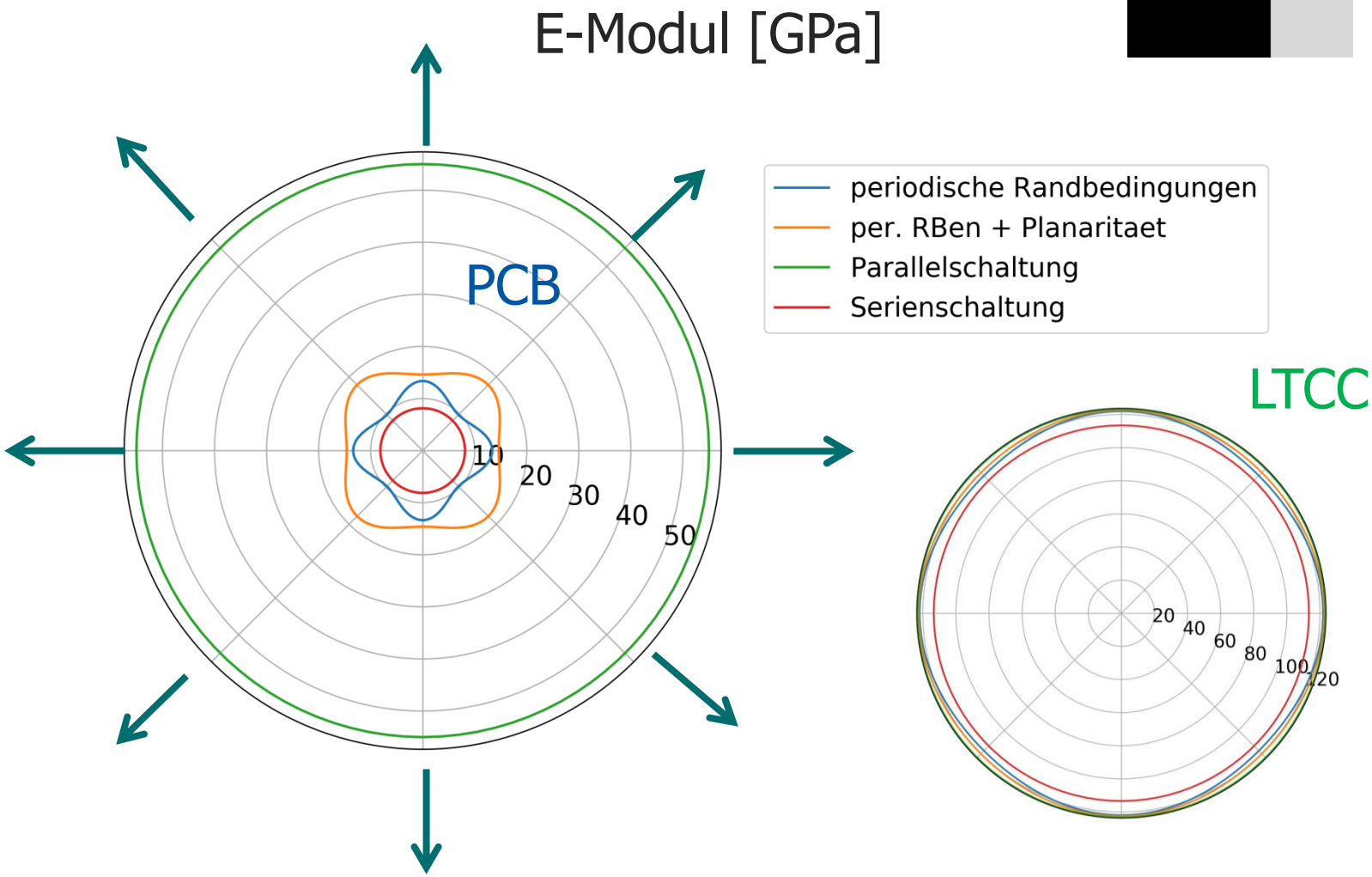
Kunststoffleiterplatte (PCB)

		E [GPa]	ν [-]	α [ppm/°C]
Matrix	Epoxy	5	0.33	52
Metallisierung	Kupfer	130	0.35	15

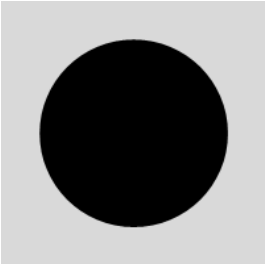
Keramische Leiterplatte (LTCC)

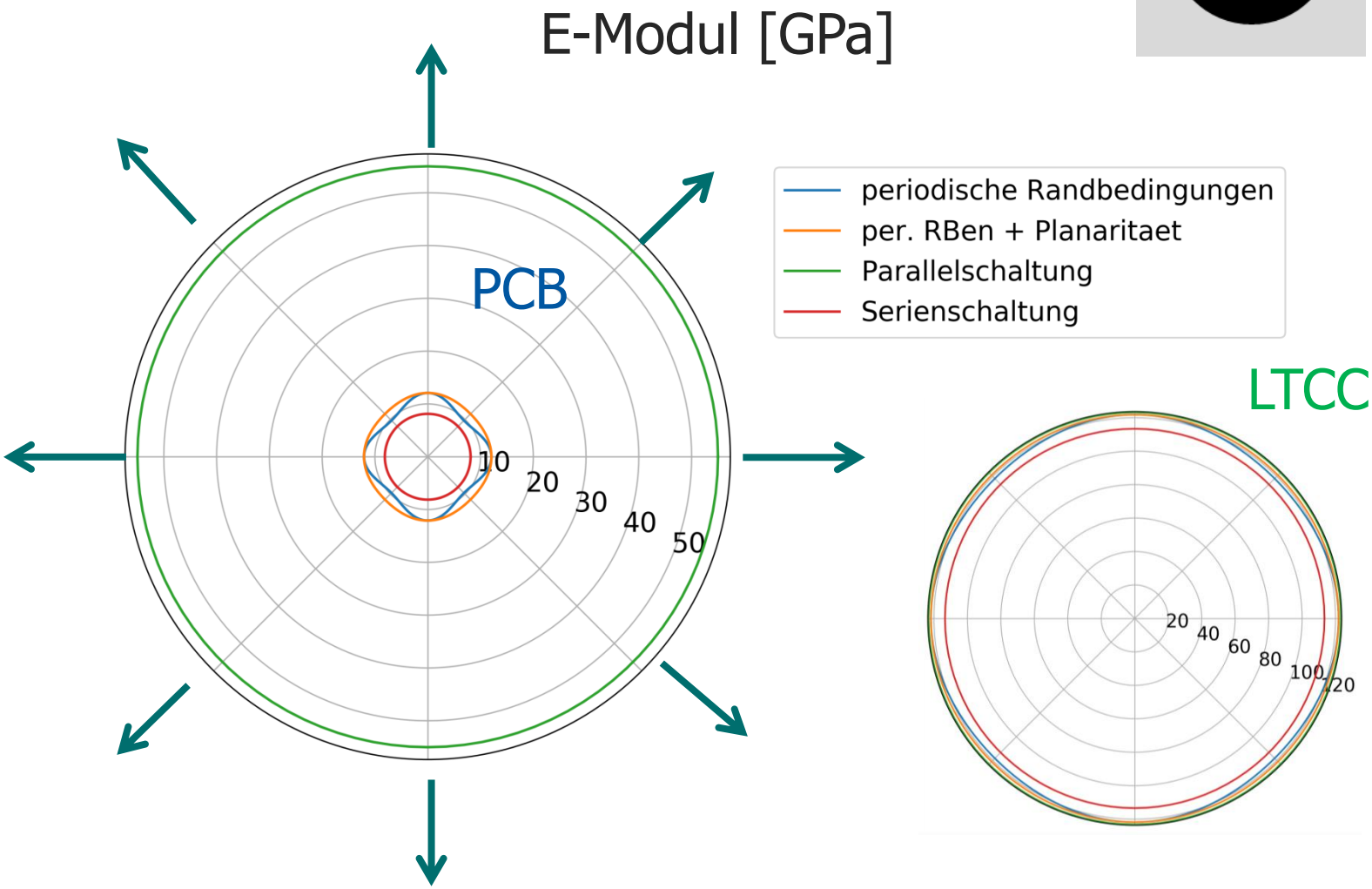
		E [GPa]	ν [-]	α [ppm/°C]
Matrix	LTCC	150	0.236	7.5
Metallisierung	Silber	83	0.37	21

Richtungsabhängige Steifigkeit

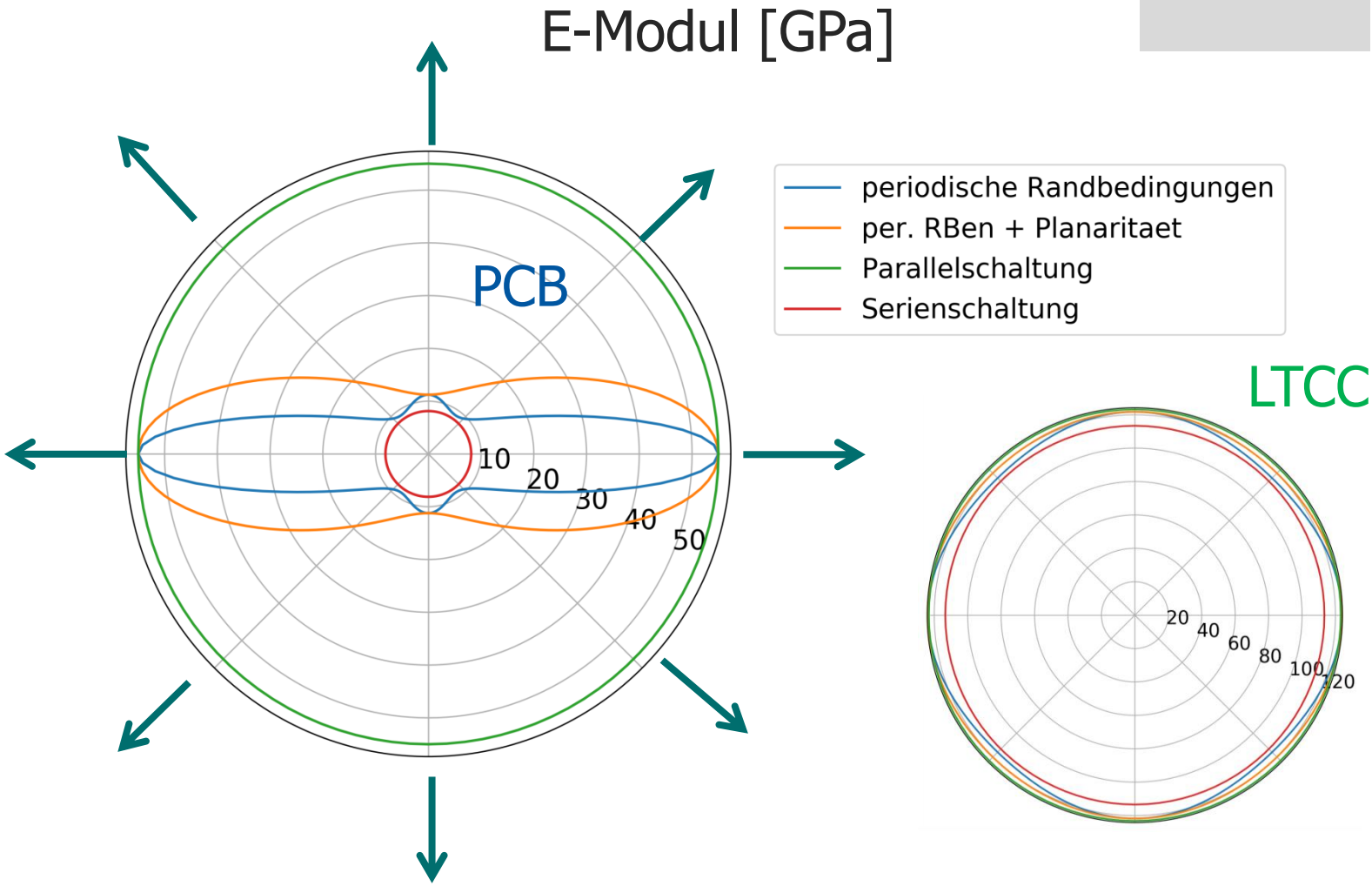


Richtungsabhängige Steifigkeit

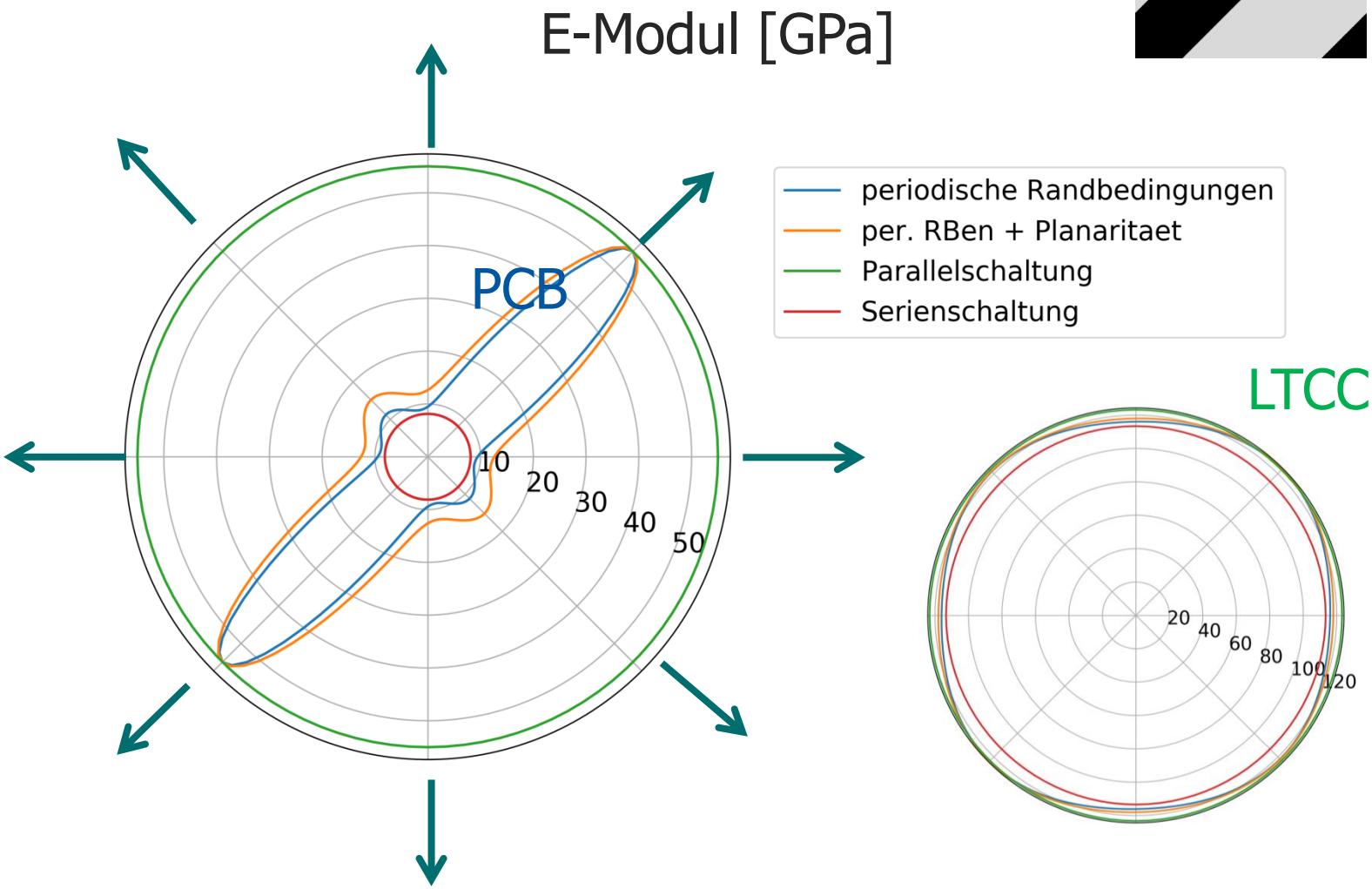




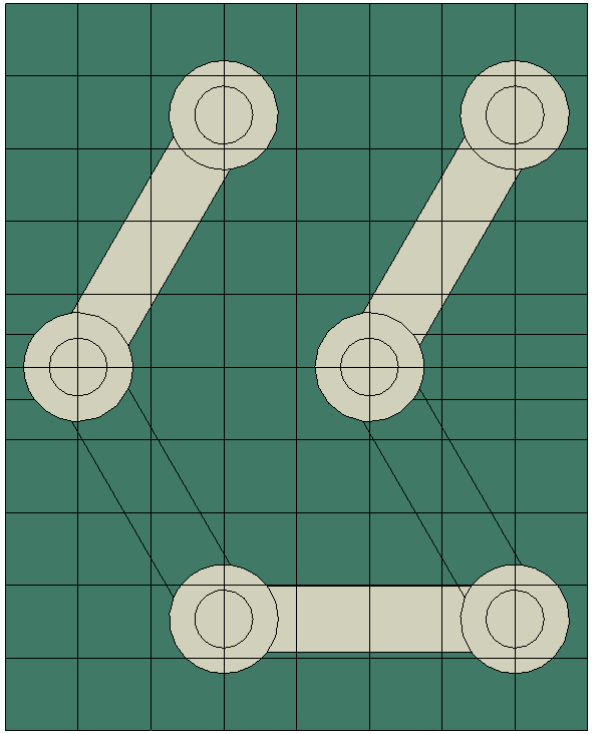
Richtungsabhängige Steifigkeit

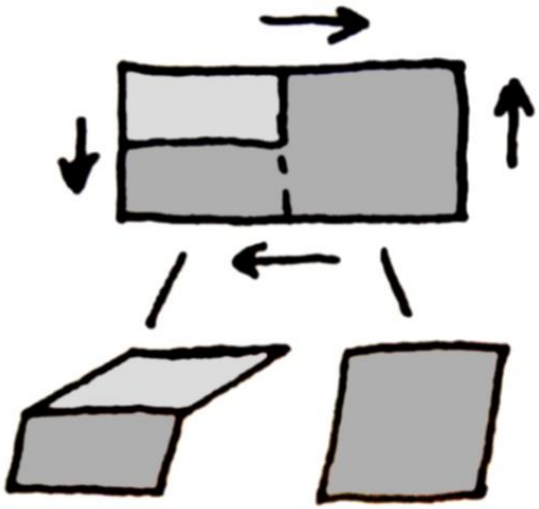


Richtungsabhängige Steifigkeit



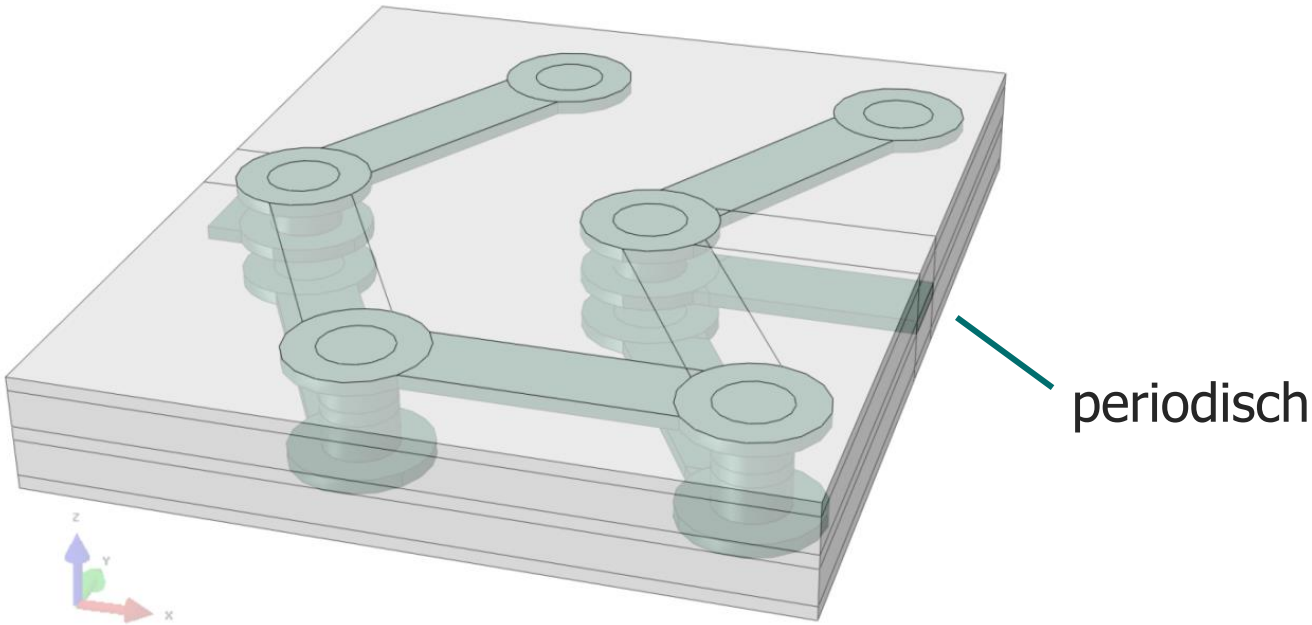
Problematik Homogenisierung





→ Randbedingungen an Zellen?

Prinzipstruktur: Vergleich der Ansätze



Variation von:

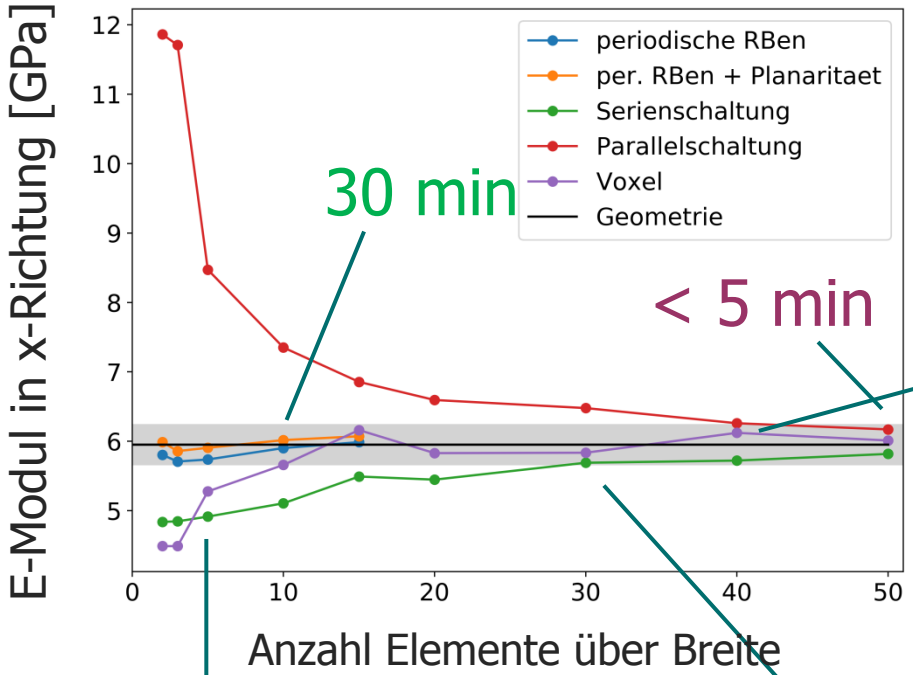
- Material (PCB oder LTCC)
- Anzahl Unterteilungen
- Berechnungsmethode Zelleneigenschaften

Ermittelt:

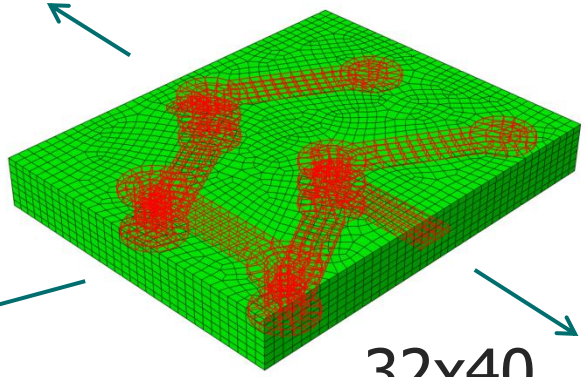
a) Rechenzeit
b) Genauigkeit

E-Modul in x-Richtung

PCB

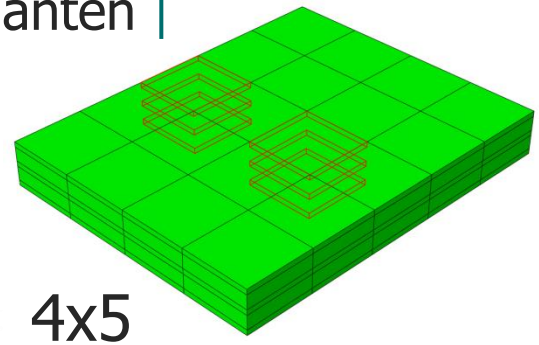


volle Geometrie

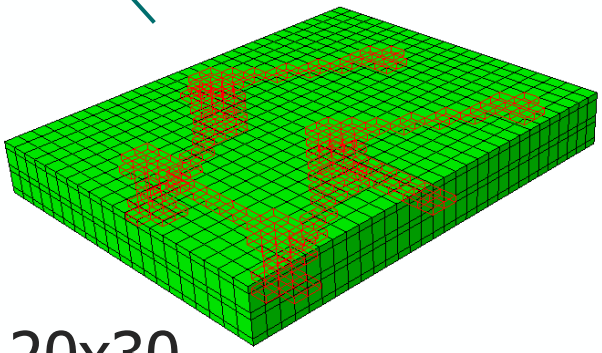


32x40

Voxelvarianten

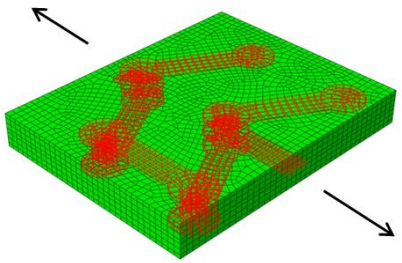


4x5



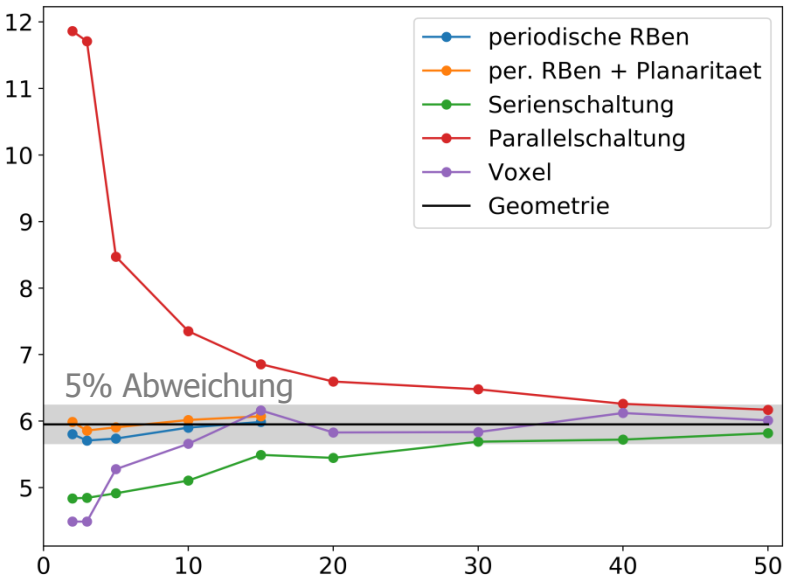
20x30

E-Modul in x-Richtung



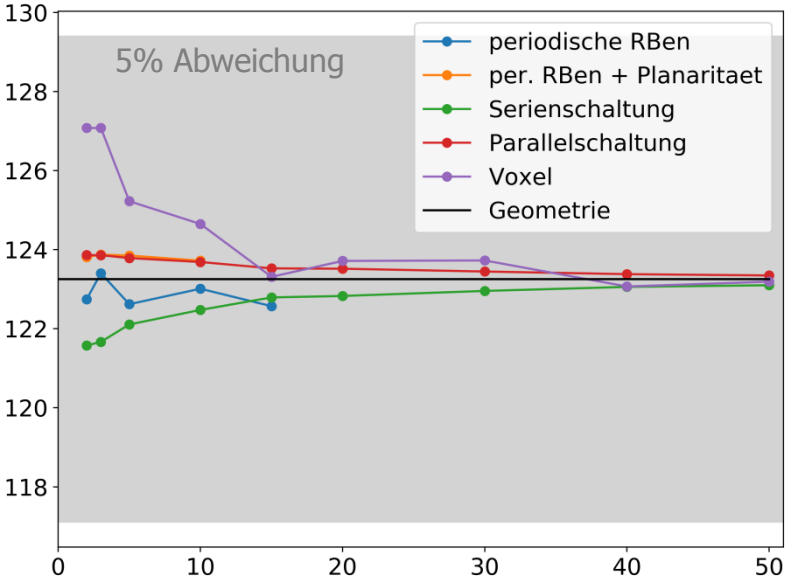
E-Modul in x-Richtung [GPa]

PCB



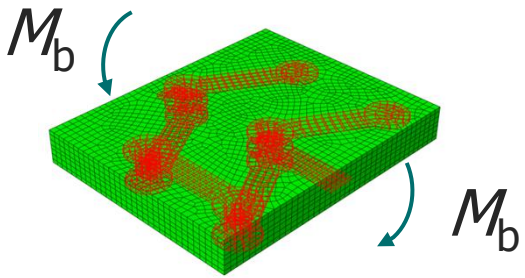
Anzahl Elemente über Breite

LTCC

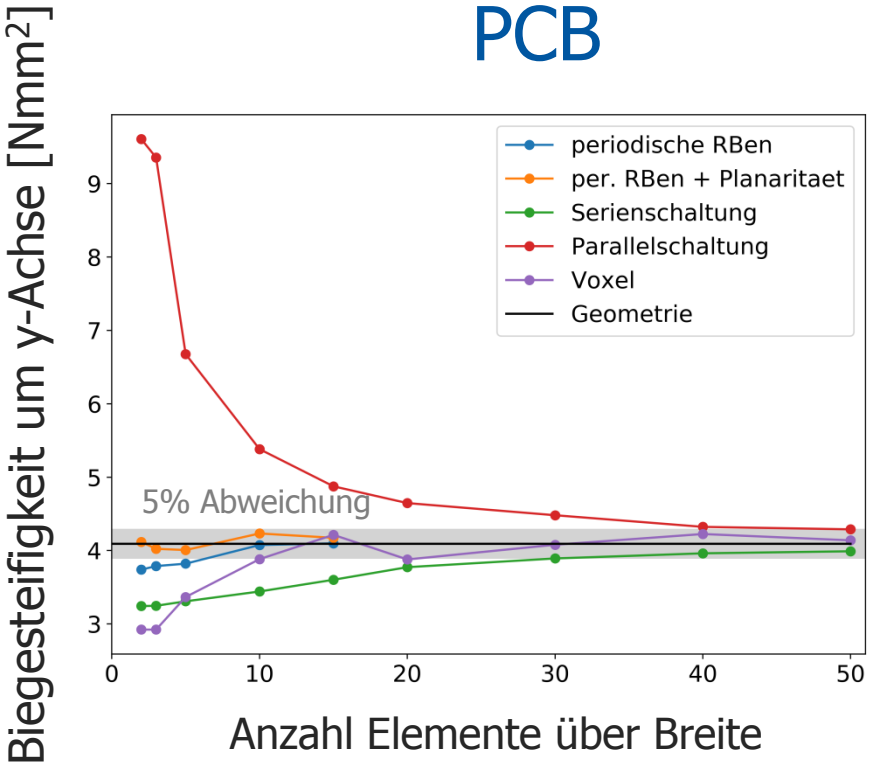


Anzahl Elemente über Breite

Biegesteifigkeit y-Richtung



PCB



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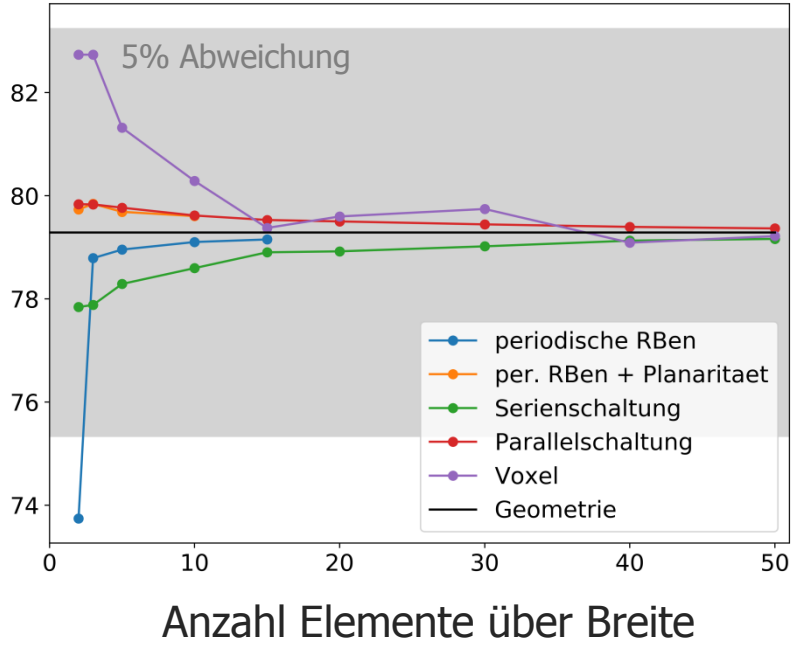
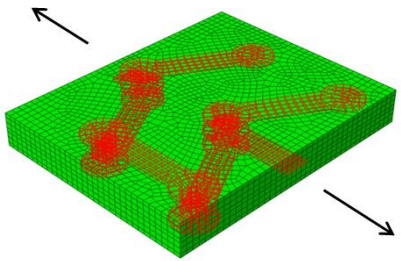


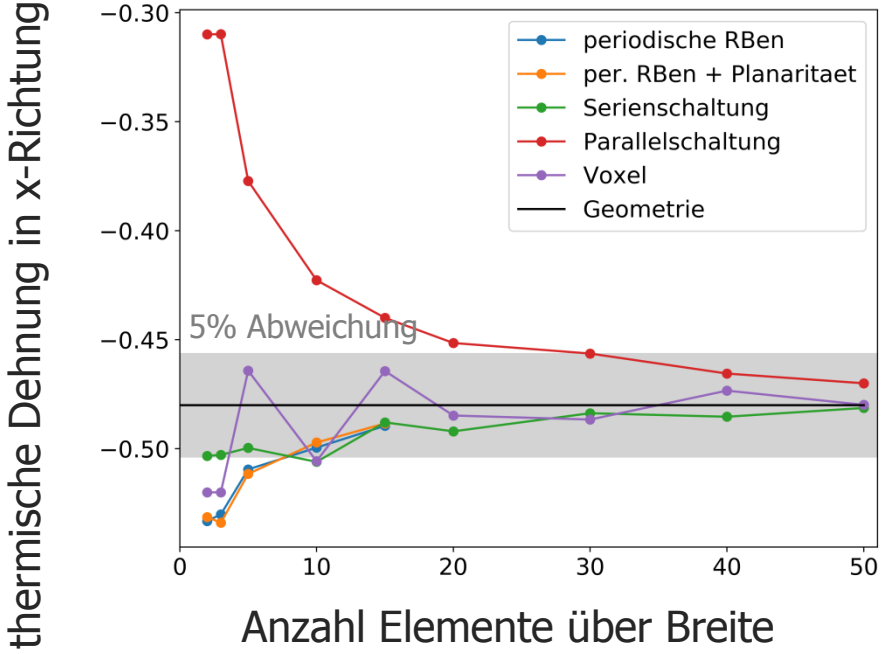
Wärmedehnung in x-Richtung

Dehnung ε



ΔT = -100 K

PCB



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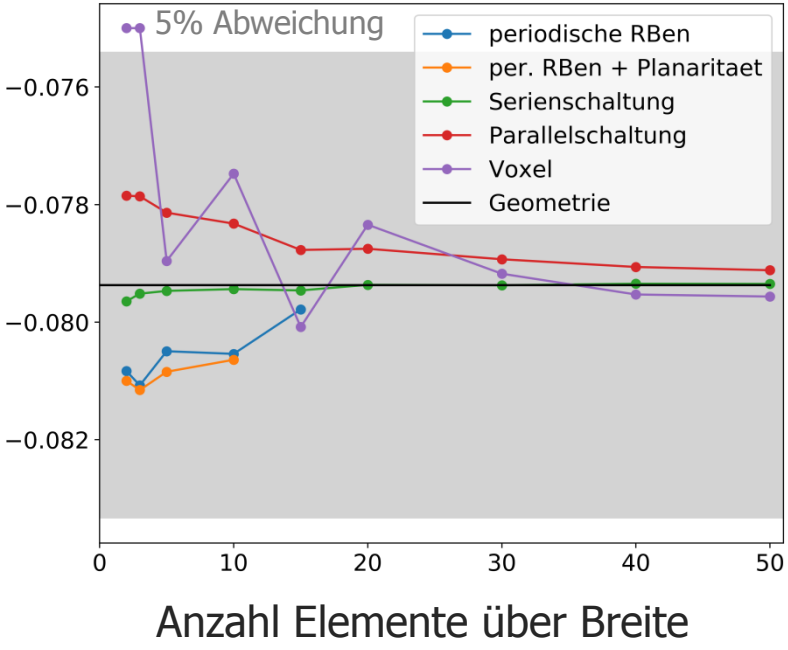
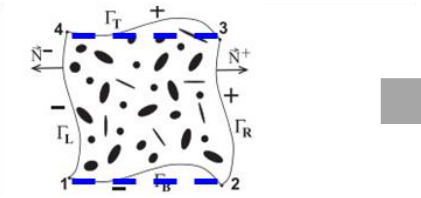


Schlussfolgerungen

- Leiterplatten: Großer Aufwand für Simulation
- Homogenisierungsansätze:
  - große Steifigkeitsunterschieden: feine Diskretisierung notwendig
  - FE Methoden für Zelleneigenschaften: Besser, aber viel langsamer

per. RBen + Planarität



semi – analytische Berechnung?!