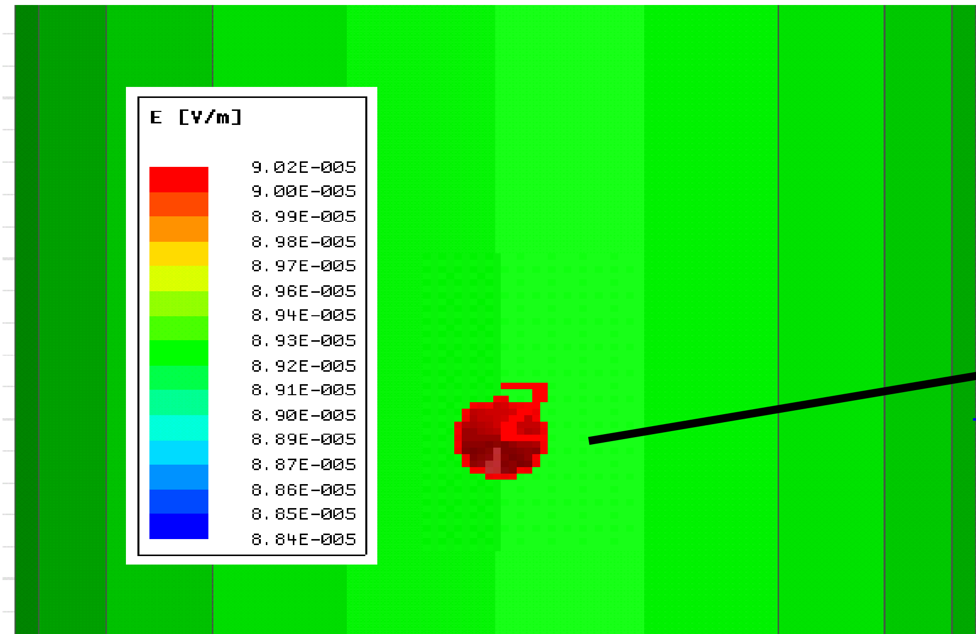
Simulation in Power Electronics Design

Simulation, Possibilities, and Issues

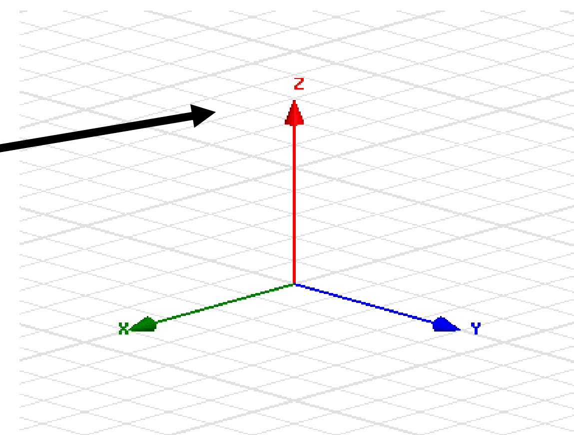
Where is the highest electric field strength?

Example – illustration of the electric field strength



Guess: local maximum

Actually: coordinate system

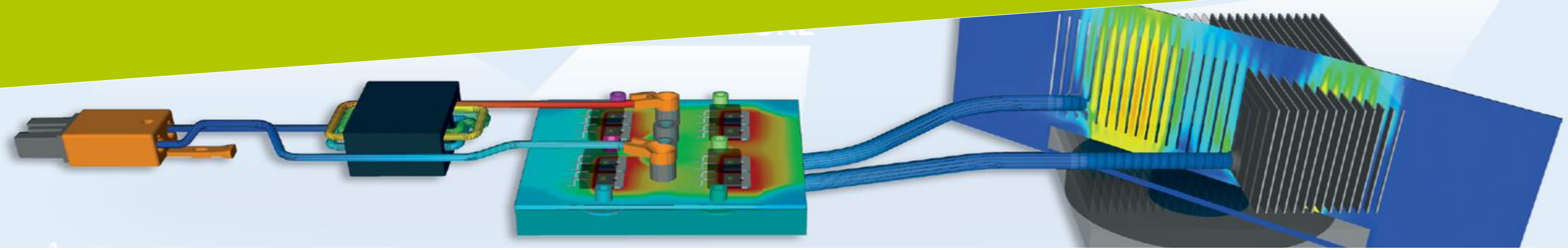


Content

- What do we simulate?
- Fundamental considerations
- Common mistakes…

PACKAGING

Multiphysics Simulation for Power Electronics



Simulation Subjects

- Electrical, thermal, and mechanical simulation on device, module, and system level
- Electronic cooling design, thermal management
- Coupled and multiphysics simulations
- Extraction of electric parasitics and circuit simulation
- Simulation - design - optimization - verification by measurement

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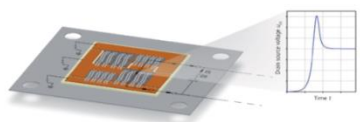
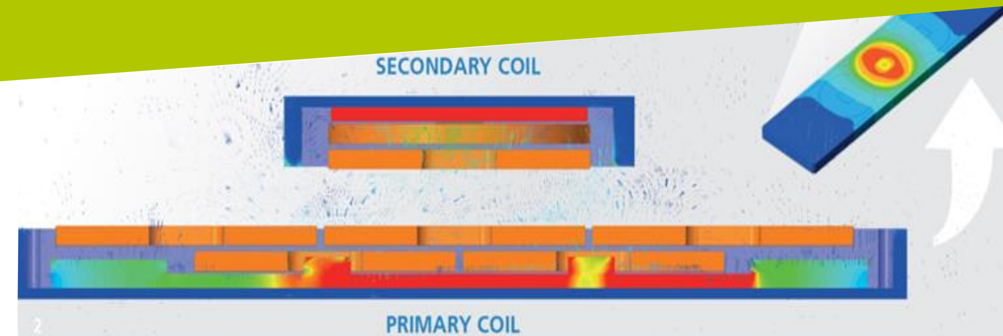
Electromagnetics

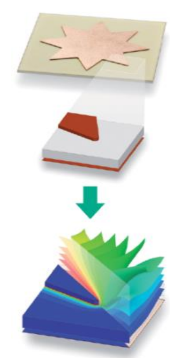
Simulation





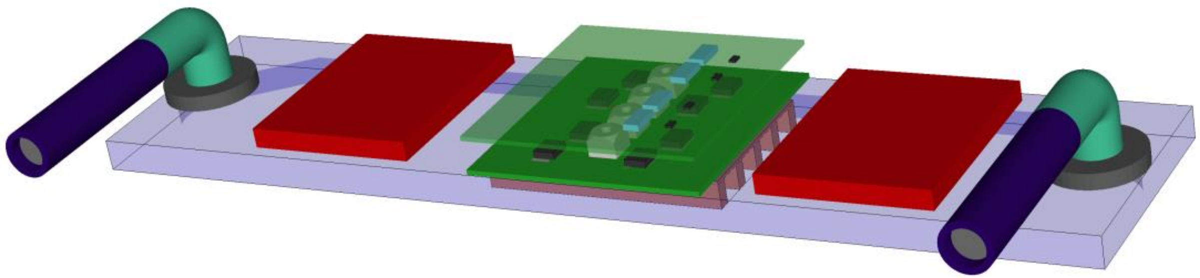
Electromagnetics

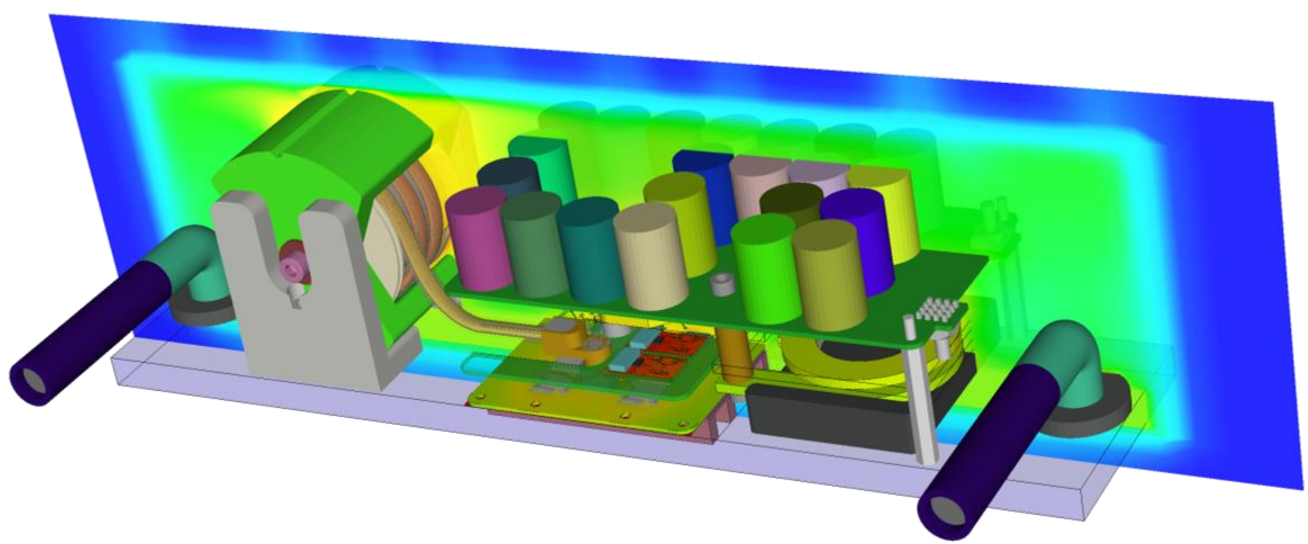
- Electric current, potential and field strength distribution analysis
- Identification of critical areas of the insulation due to high field strengths
- 3D and 2D extraction of parasitics in electronic packaging
- Computation of the capacitance, conductance, inductance, and resistance matrices



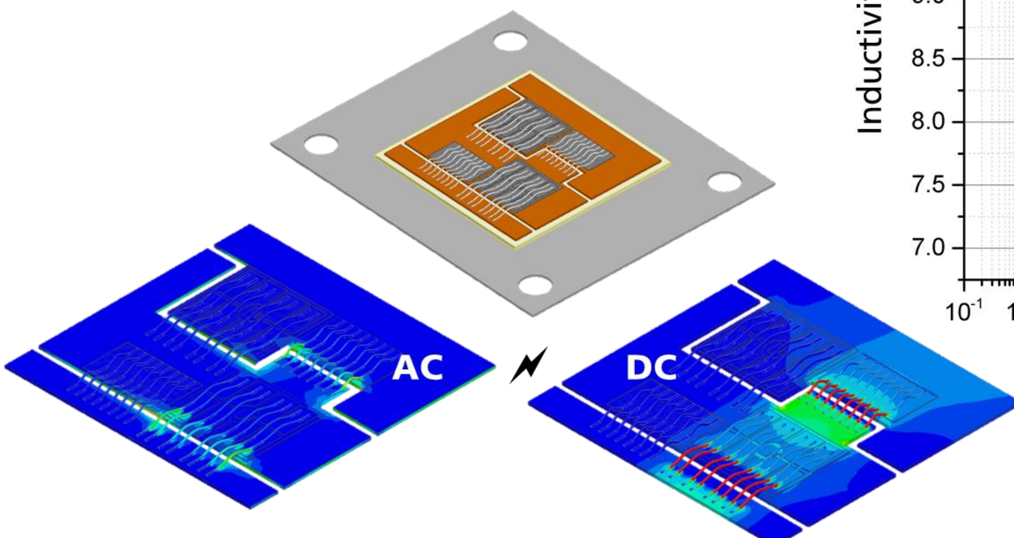
- Generation of a netlist by extracted LCR parameters of any design (e.g., SML of SPICE format)
- Calculation of the inductance and capacitance
- Values of PCB or standard power module designs as well as of sensors and other similar applications

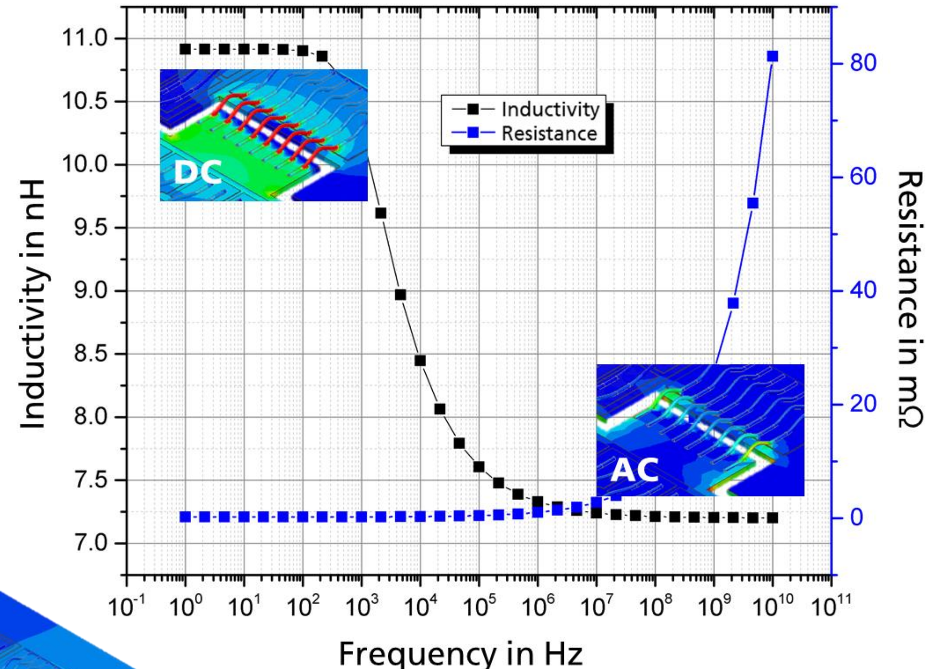
Electronic Cooling Design and Thermal Management





Parasitic Extraction and Electric Current Distribution





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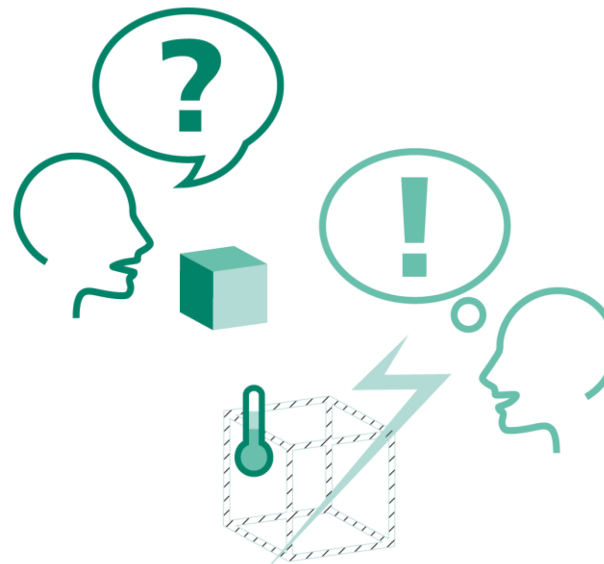
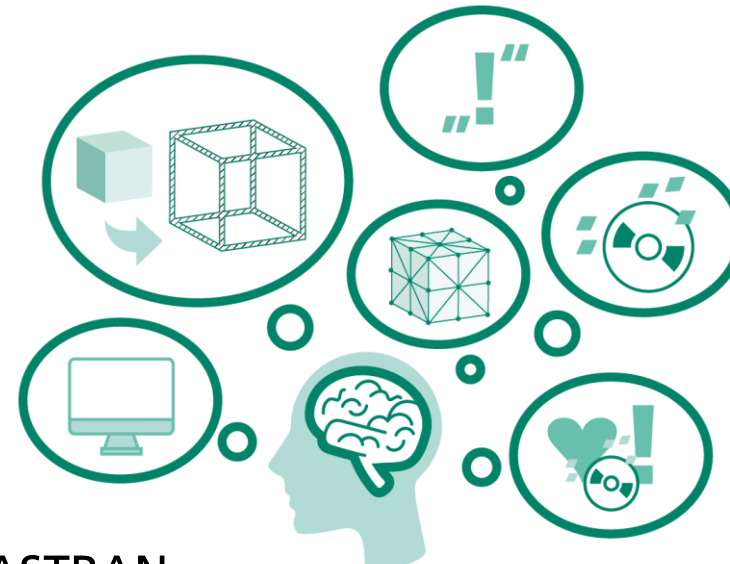
What is Simulation?
Expectations

- Building understanding of the problem and the materials involved
- Extension of the impact of physical processes and behavioral prediction
- Reduction of development time, development costs and production costs - material savings - reduction of test series
- Early detection of vulnerabilities, Failure prediction
- Quality improvement and optimization of the construction
- Flexible adaptation to subsequent constructions
- Training
- And much more…



What is Simulation?
Demands



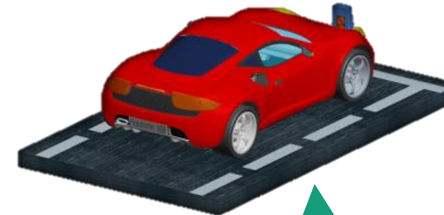
1. Understanding of the modelling (Experiment → Calculation Model)
2. FEM theory: Knowledge of the basics
3. Training time for the software
4. Powerful and problem specific software (ABAQUS, COMSOL, PLM, CST, ANSYS, JMAG, ISAFEM, MECHANICA, NASTRAN, PERMAS, CD-Adapco, FEMM, OpenFOAM, Keysight ADS, 6SigmaET, etc.)
5. Powerful hardware (workstation, mainframe computers, clusters, cloud)
6. Expert or engineering knowledge for the critical evaluation of the results

What is Simulation?
Principle course

The integration of simulation into development and research processes leads to various intermediate steps:

- Transfer of the real problem in terms of geometry and physics into a simulation model
- Calculation of the target values based on the given boundary conditions for a specific physical system
- Verification by measurements
- Parameterization and optimization of the model
- Analysis, visualization and evaluation of results

What is Simulation?
Principle course

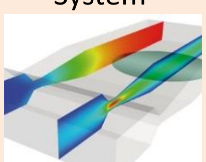


Geometry

Micro

Macro

System



Physic

Thermo-dynamics
Electrical
Structure
Fluid mechanics
Acoustics
Diffusion
Radiation
Lifetime

Mathematic Methods

FDM
FEM
FVM
BEM
...

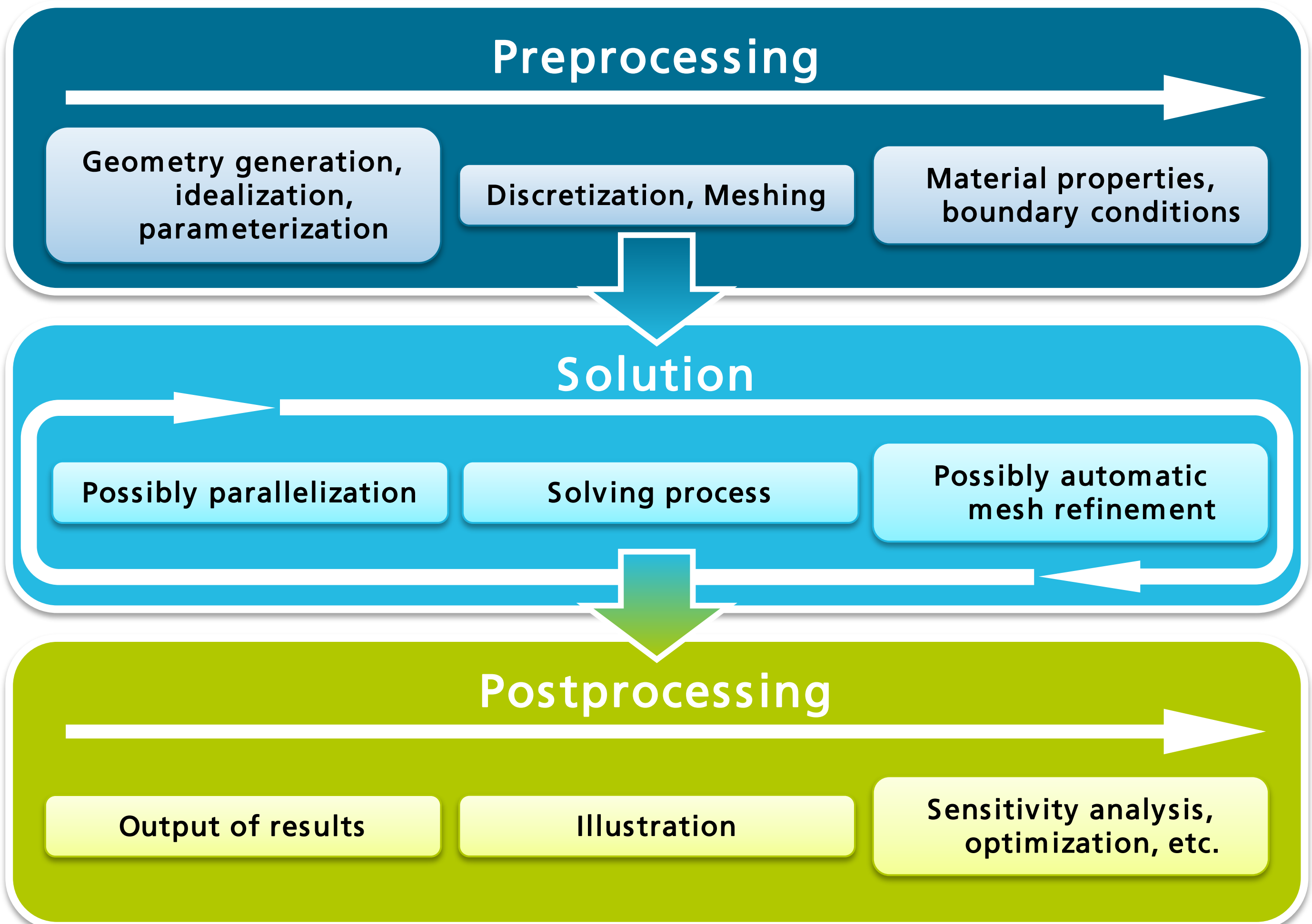
Implementation

Single Core
Parallel
GPU
...

Visualisation

Contour-Plot
Particle tracing
2D curves
Vector-illustration
False-color image
Diagramm
Clip
...

Routine of a FEM simulation



What can be simulated?

Options for simulation… almost everything

- Static and dynamic strength calculations, electrical, electromagnetic, magnetic, thermal, mechanical, thermomechanical, vibration mechanical problems
- Chemical and physical reactions, separation processes or combustion processes
- Vibration analysis of electrical machines, stresses and deformations (elastic and plastic, e.g. virtual crash tests using finite element methods), fluid simulation
- Semiconductor devices, thermal conduction, optical systems, fusion reactors, accelerators and nuclear reactions, doping and diffusion, electromigration, electrical properties, circuit simulations

➢ Couplings, reductions, optimizations, ...

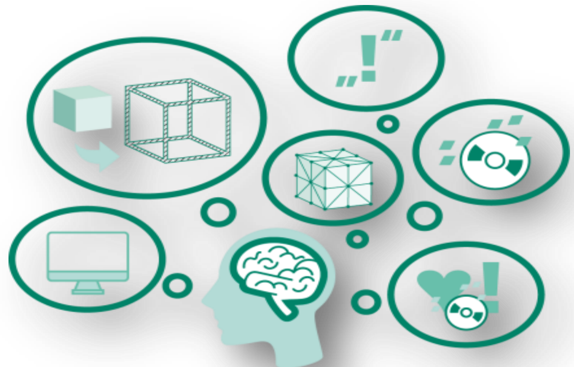
Outlook on the FEM simulation
Acceleration, simplification, linking and optimization

- Linear physical behavior (e.g., temperature distribution) enables 'Model Order Reduction' (e.g., CADFEM MOR, meta-models)
- Due to strong refinement + Plenum → BEM / Circuit → Q3D
- Coupling between different 'physics' - different meshs

- From the calculation of a specific operating point, there are further possibilities, for example:
  - Parameter space sampling
  - Sensitivity analysis
  - Optimization

Thank you for your attention!

All clarity eliminated?



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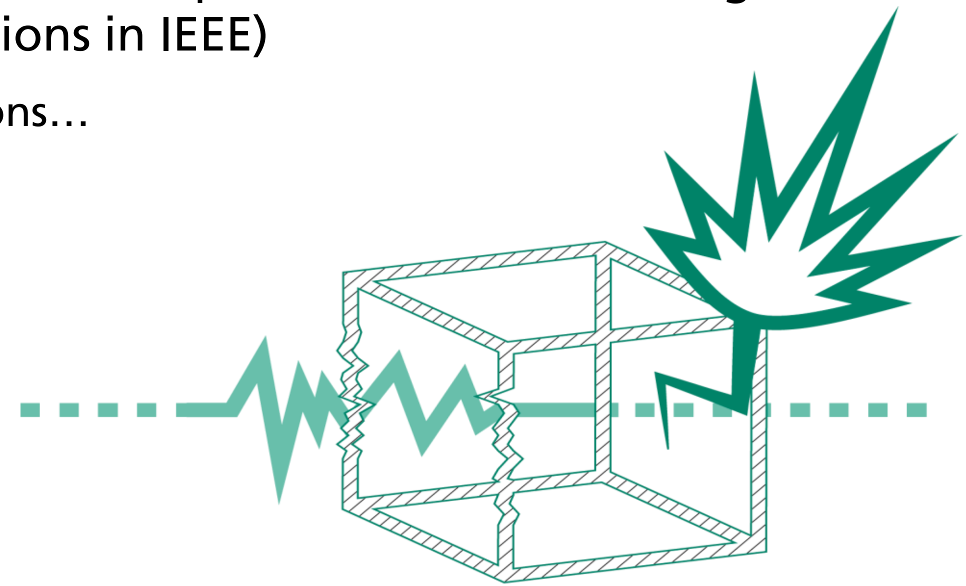
What can go wrong?
Examples

Possible errors - more common mistakes/evaluations that help to better analyze and evaluate as an editor and recipient of simulations/diagrams (all examples taken from publications in IEEE)

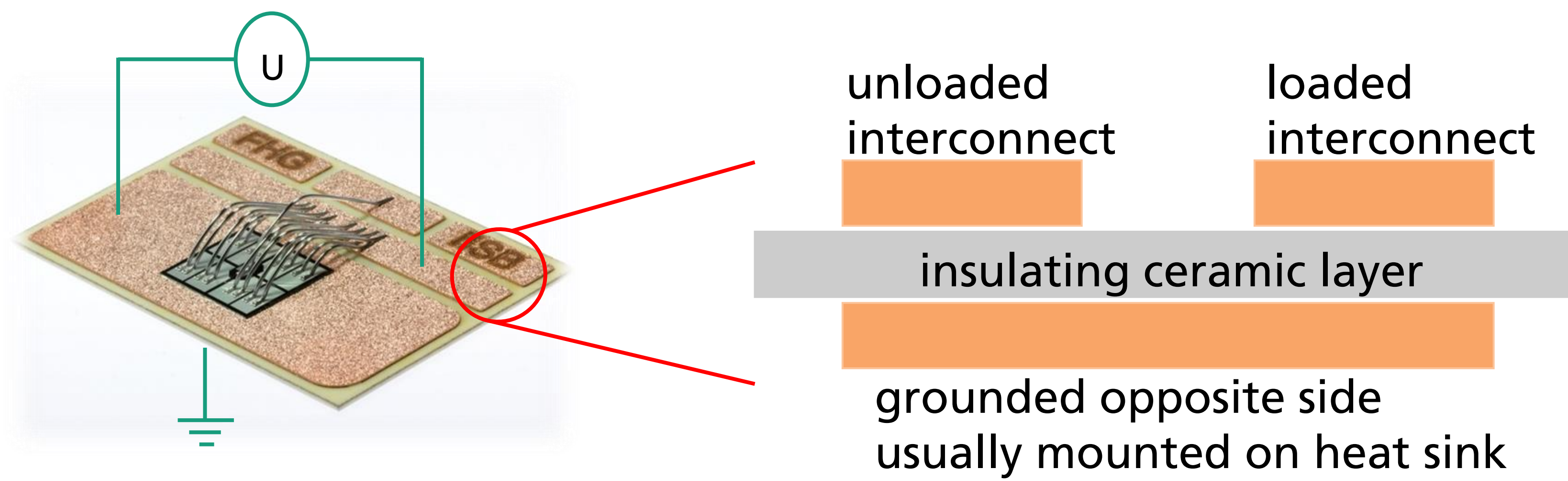
- Wrongly chosen boundary conditions…
- Evaluation of an artifact…
- Misleading illustration…



What can go wrong?
Wrongly chosen boundary conditions

Example - electrical insulation by ceramic / plastic

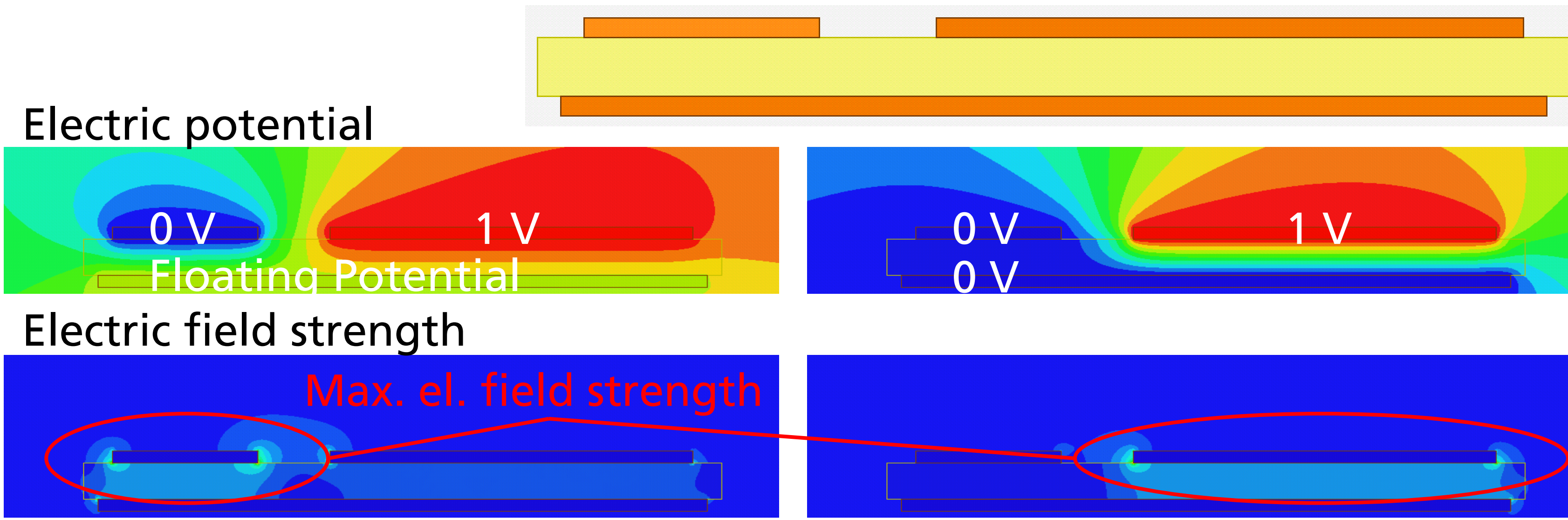
- The electrically conductive layer, which is mounted on the usually grounded heat sink, is not defined as grounded but as a floating potential or even not provided with a boundary condition



What can go wrong?
Wrongly chosen boundary conditions

Example - electrical insulation by ceramic / plastic

- Consequence: The critical position for the electric field strength is erroneously identified at the edge of the unloaded copper pad



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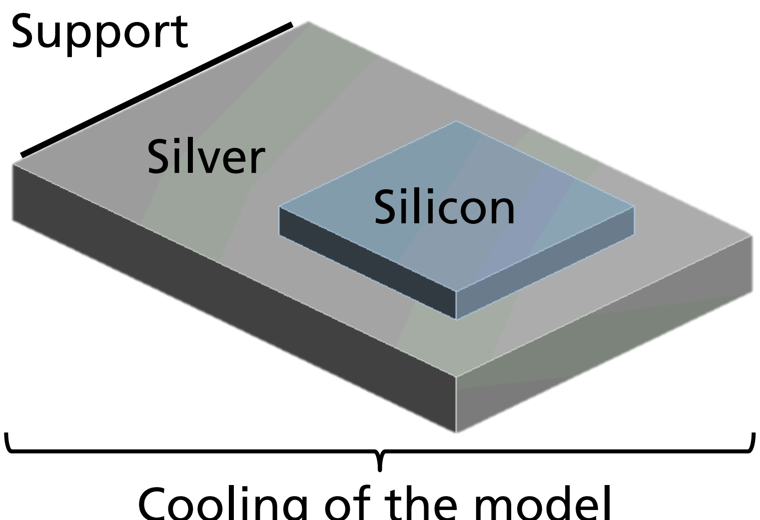
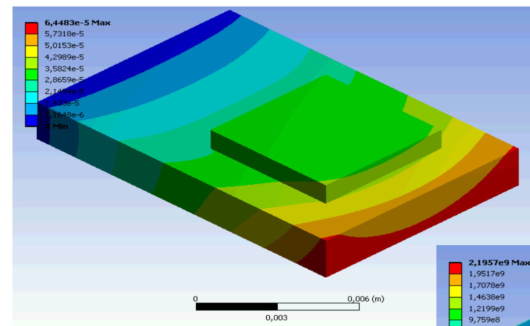
What can go wrong?
Evaluation of an artifact

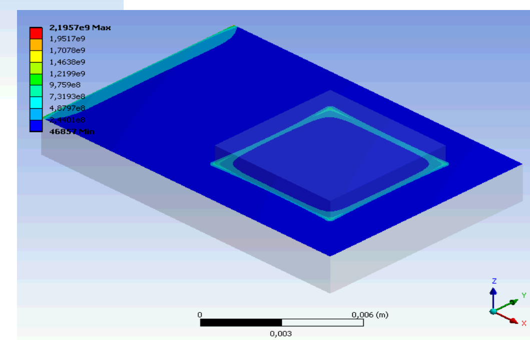
Example - Evaluation of the mechanical stress on an edge

- Evaluation of the stress at the edge of a body lying on a second body





Deformation

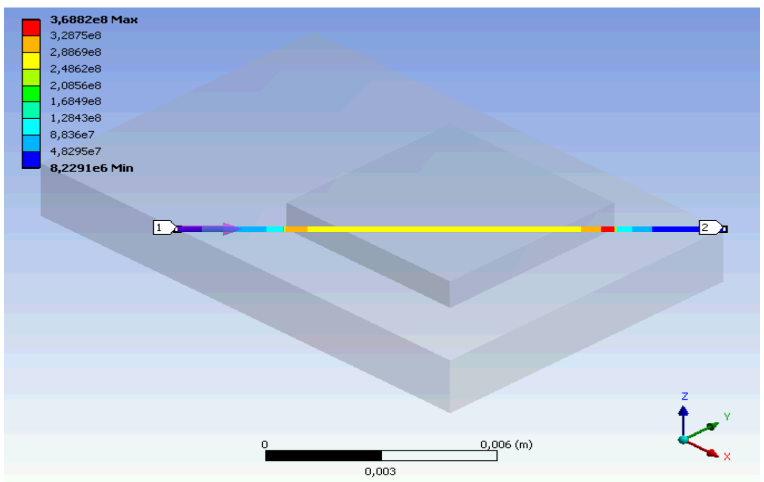


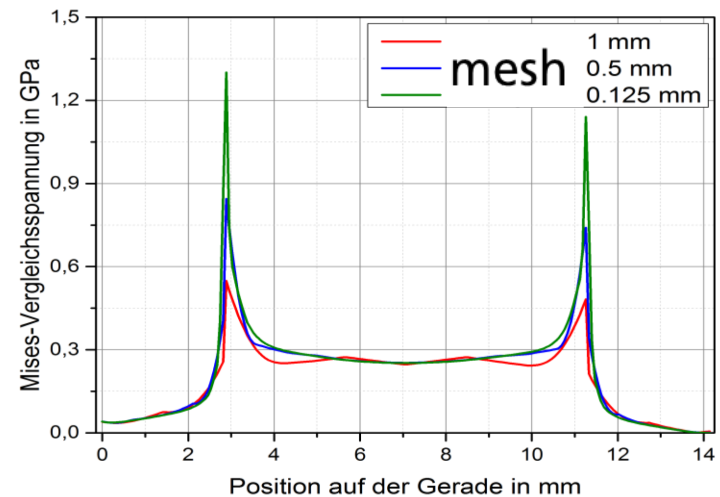
Mechanic stress

What can go wrong?
Evaluation of an artifact

Example - Evaluation of the mechanical stress on an edge

- Result: Evaluation of an artifact of the calculation or a singularity, at which the calculated value increases with increasing mesh resolution (diverges)
  → do not evaluate vertices and edges!





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