Virtual DoE → selection of molding compound based on FEM simulation

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Motivation:

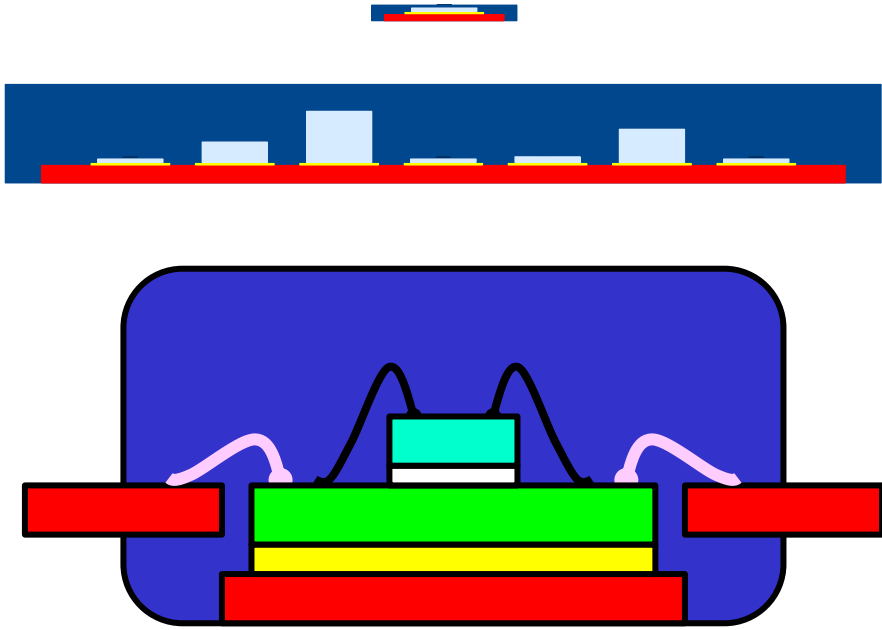
1) Complexity of the electronic control units is increasing
2) New materials in consideration
3) Shorten design cycle time

Agenda

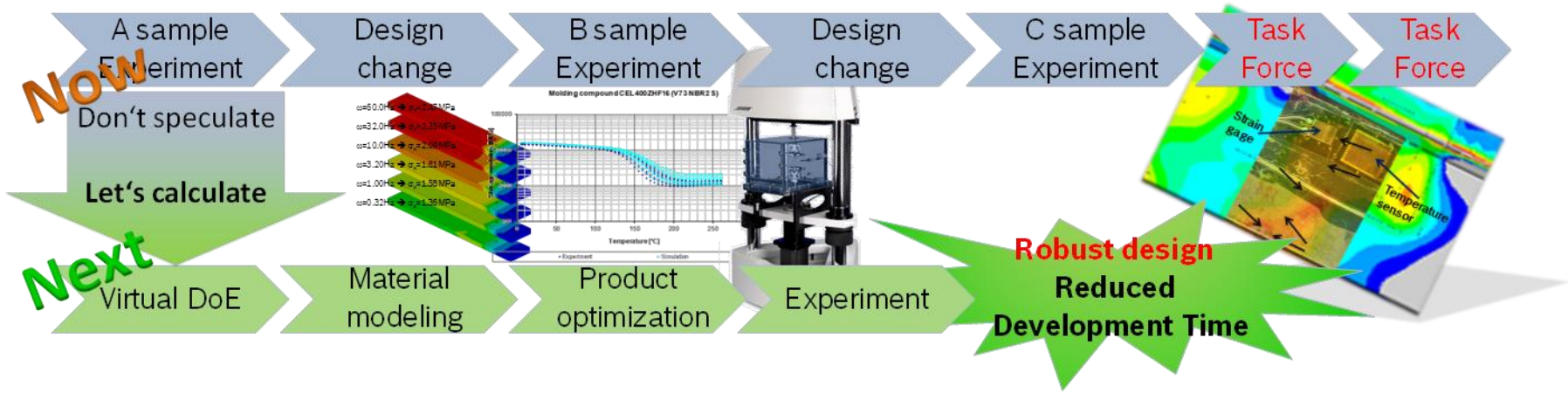
- Introduction
- Simulation driven design
- Virtual Design of Experiment
- Benefits of VDoE
- Validation of VDoE
- Summary

Introduction

- New generation of vehicles → the amount of ECUs used is increasing.
- New solution must be cost effective.
- Multi-functionality within one robust package appears to be an interesting solution.
- Relative large size of the module leads to high stress at the integrated circuitry.



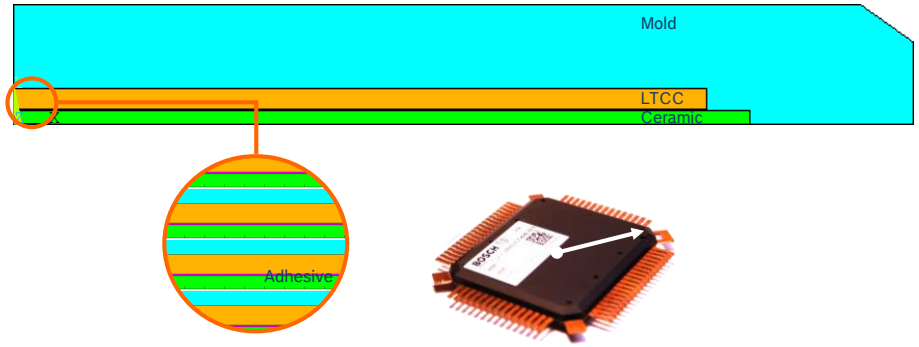
Simulation driven design

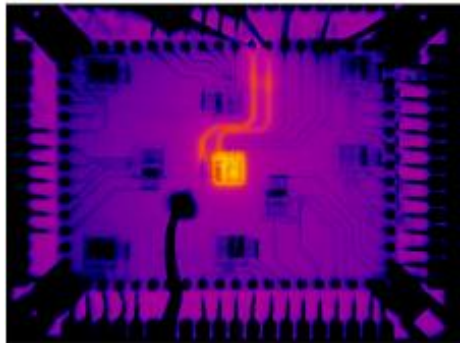


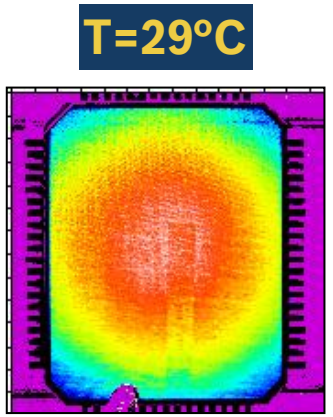
Virtual DoE has a great potential here.

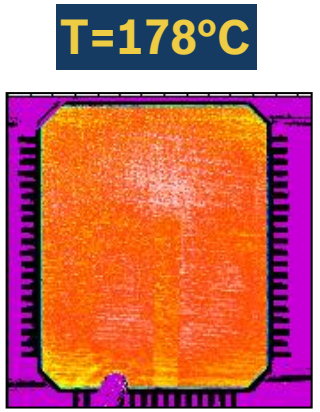
Molded electronic control unit

- Entire integrated circuitry overmolded.
- Based on LTCC technology.
- Challenges:
  - Thermal – heat generation
  - Thermo-mechanical – temperature dependent deformation









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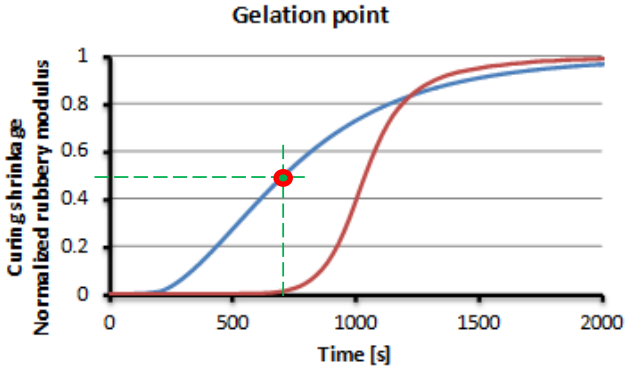
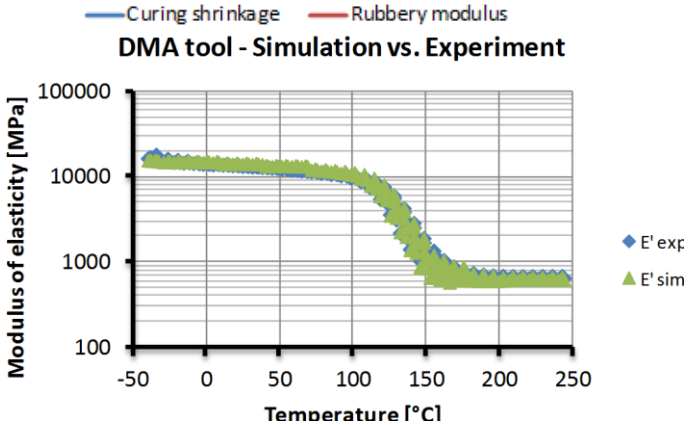
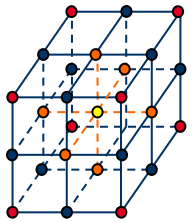
Design of experiment

Molding compound – composite material used for encapsulating of semiconductor devices and electronic control units

- Properties changes during the manufacturing process.
- Time/temperature dependent.
- Parameters of molding compound (DoE design):
  - CTE1 – 6 … 20 [ppm/K]
  - CTE2 – 25 … 50 [ppm/K]
  - Tg – 100 … 200 [°C]
  - Shrink – 0.0 … 0.4 [%]
  - E – 12500 … 30000 [MPa]

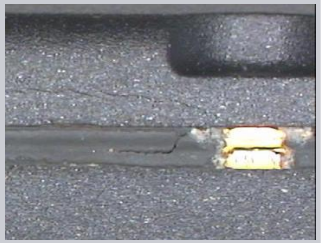
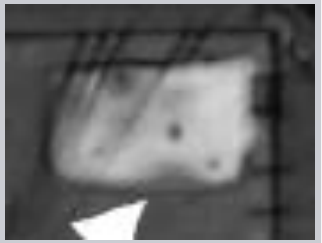
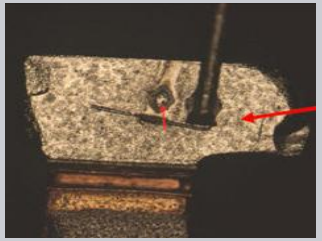
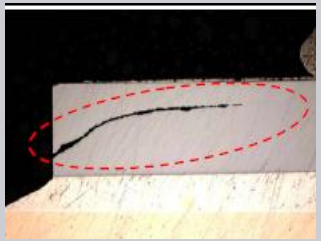
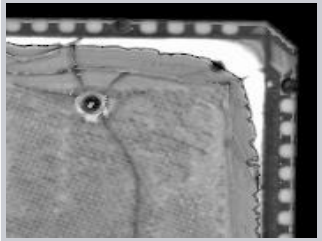






Covers wide range of available molding compounds

Typical failure mode in semiconductor

Crack in molding compound	Delamination	Wire bond lift off	Crack in silicon	Crack in substrate
				

Can the prognosis be made for all possible failure modes?

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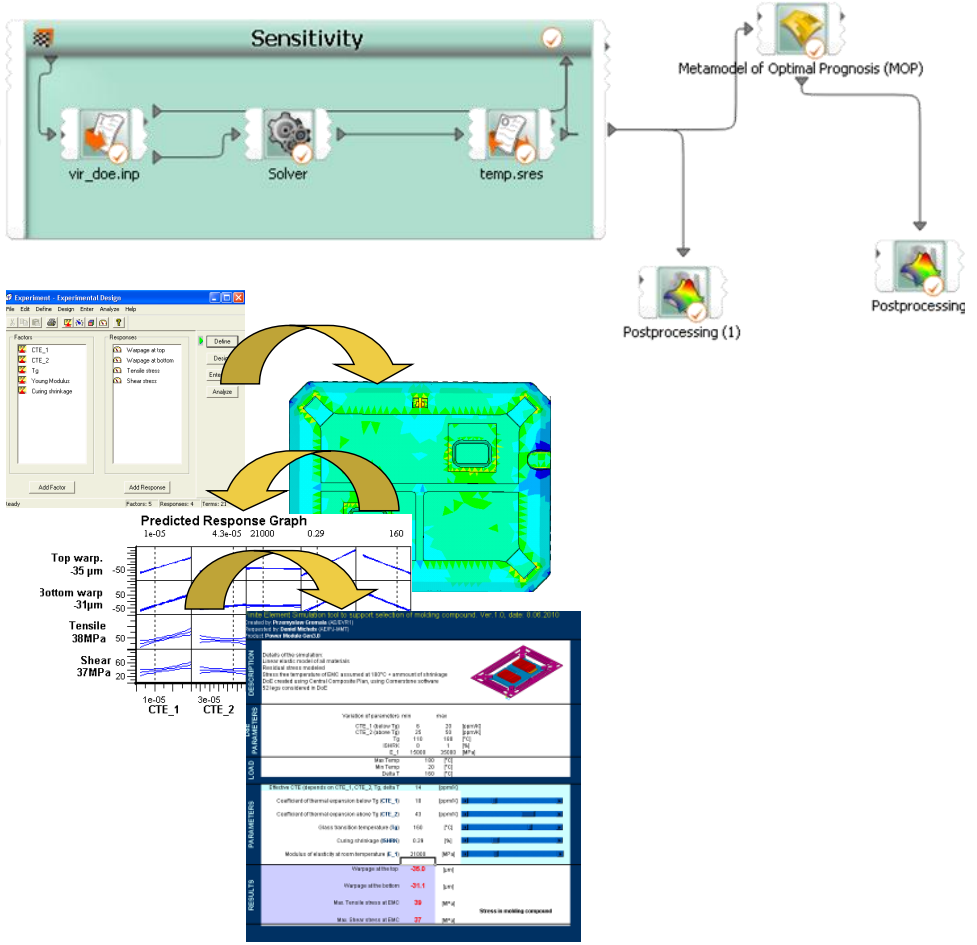
Optimization schemes

Understand the effect of the molding compound properties on the stress in molded control unit.

- Parameter identification – OptiSLang:
  - Sensitivity analysis.
  - Metamodel of optimal prognosis (MOP).
- Design of experiment – Cornerstone.



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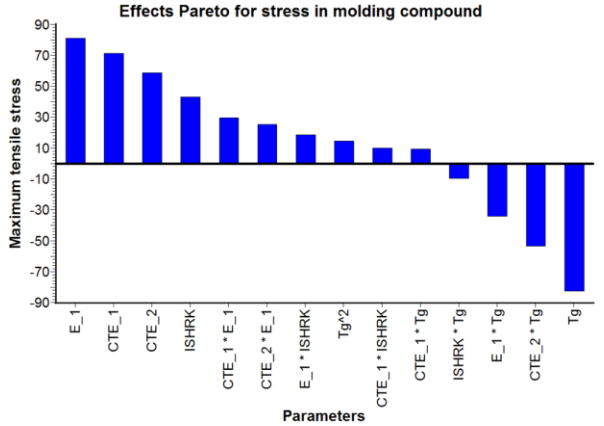
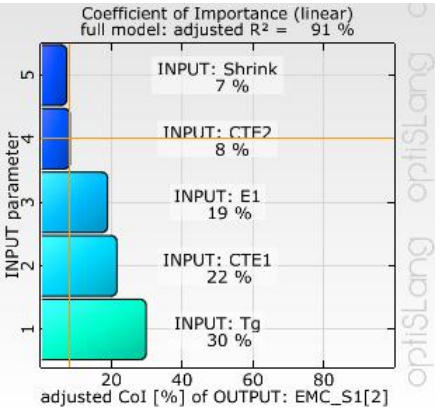
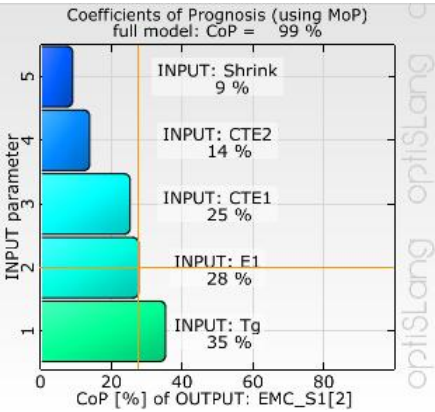
Stress in the mold

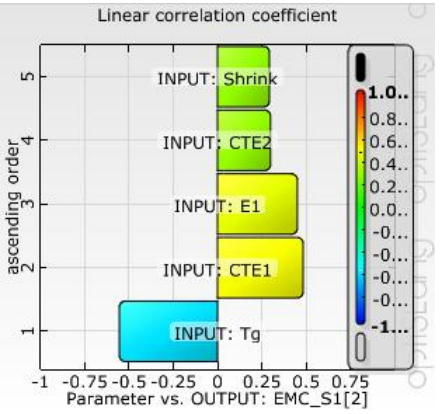
Reduce the risk of the molding compound fracture.

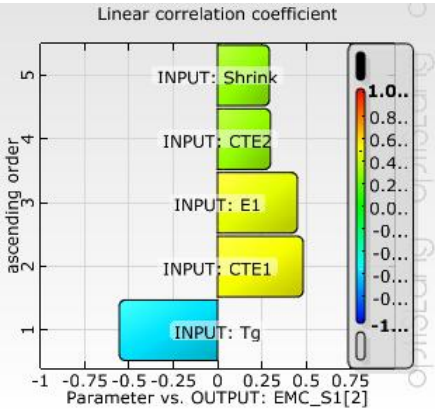
- What influence the stress
  - Main parameter is Tg.
  - CTE and E are the second most important factor.
- **Recommendation: high Tg, low CTE and low E.**











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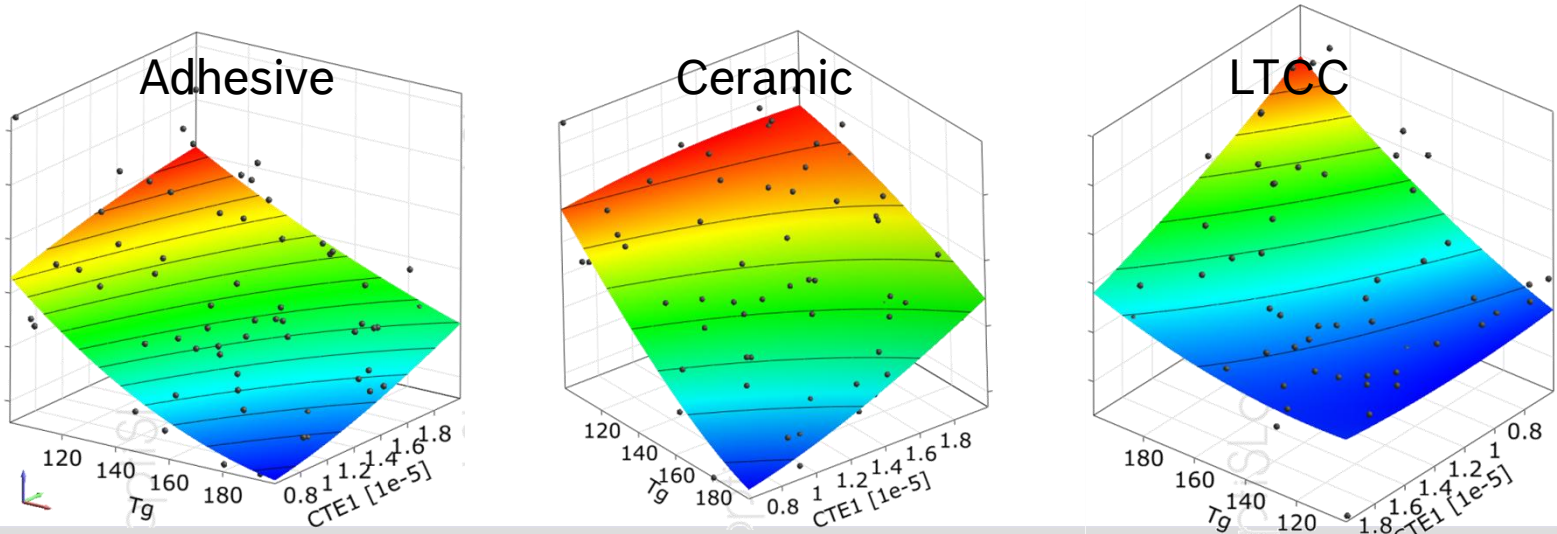
Stress in adhesive, ceramic, LTCC

Reduce the stress in the all other materials.

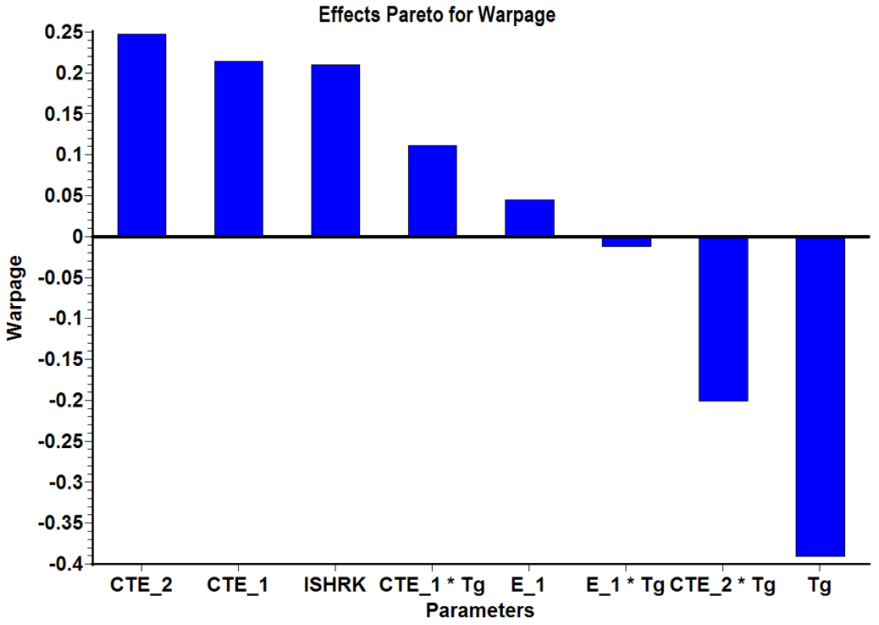
- What influence the stress:
  - Glass transition temperature is the most important parameter.
  - CTE plays second most important role.
  - Modulus of elasticity of molding compound doesn't play significant role.
- **Recommendation: Higher Tg and lower CTE.**



Warpage

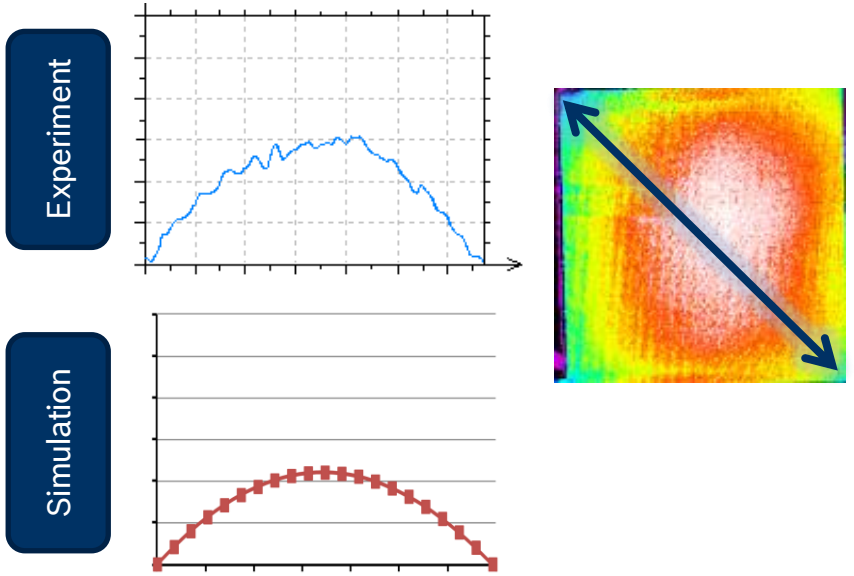
Deformation over the temperature should be low.

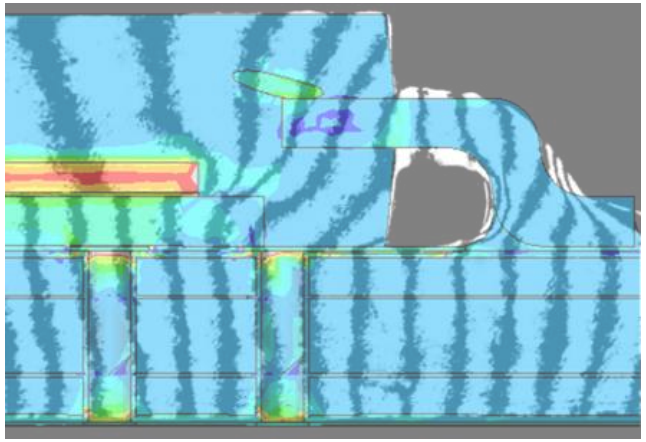
- What influence the warpage
  - Main parameter is Tg.
  - CTE and curing shrinkage are the second most important factor.
  - Modulus of elasticity doesn't play important role.
- **Recommendation: high Tg, low CTE and curing shrinkage.**

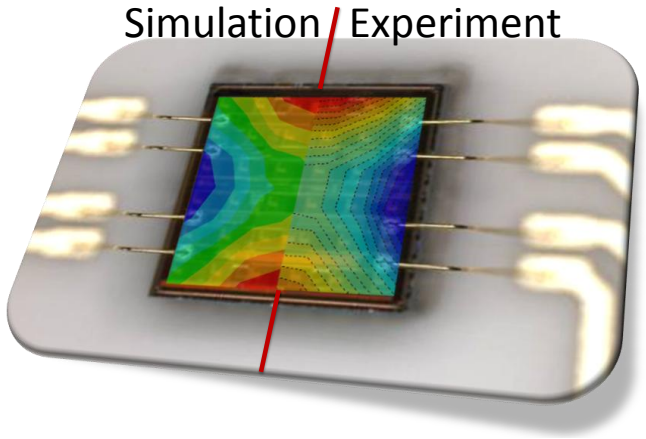


Validation

W. Beveridge: "*no one believes an hypothesis except its originator but everyone believes an experiment except the experimenter*".







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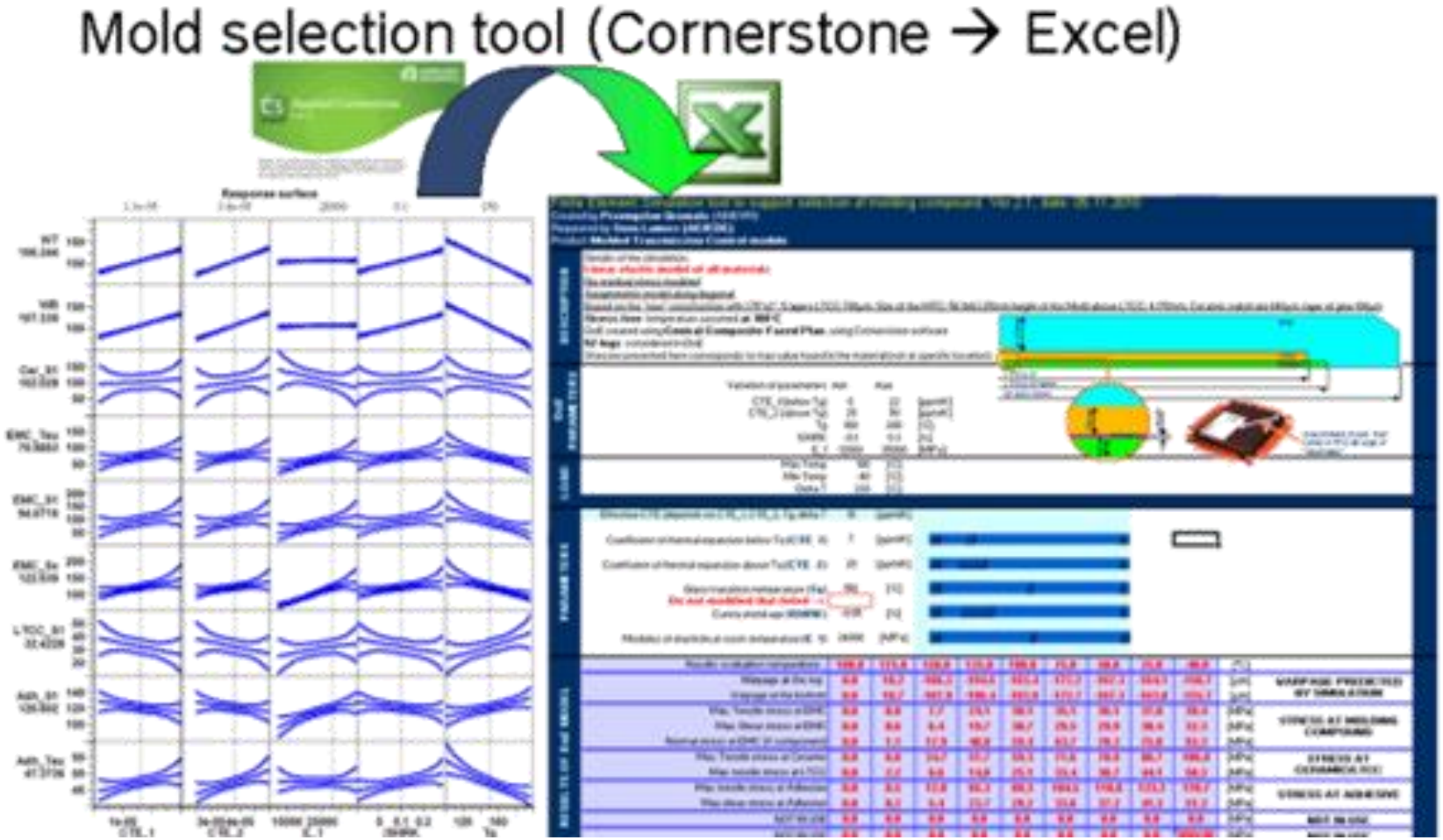
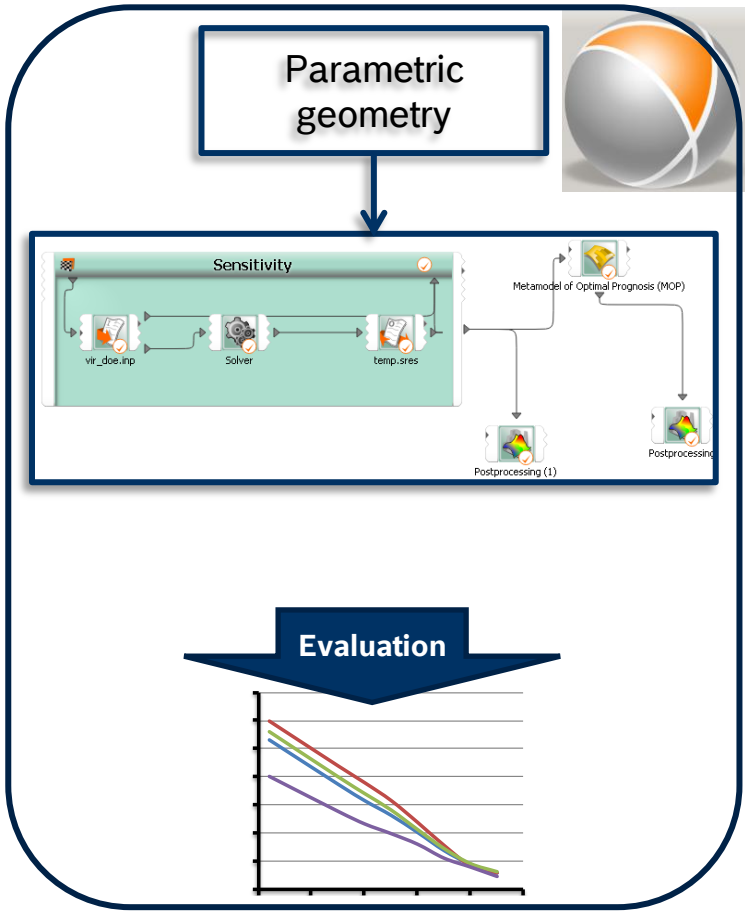
Concept of the Virtual Design of Experiment for Development of the Molded Electronic Control Units

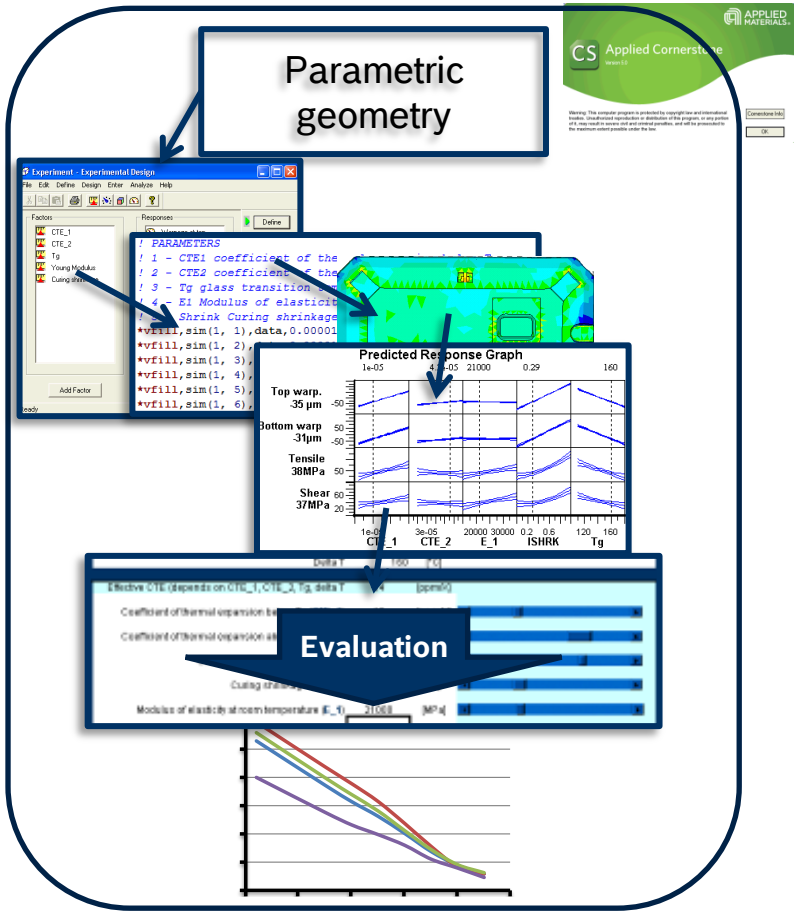


FEM vs. OptiSLang vs. Cornerstone

	FEM simulation REFERNCE	OptiSLang COI Quadratic	OptiSLang COP	Cornerstone
Warpage [%]	100	**99.9**	**98.0**	101.6
Stress in mold [%]	100	**104.1**	**101.6**	96.9
Stress in adhesive [%]	100	101.5	**101.0**	**103.2**
Stress in LTCC [%]	100	100.5	**99.7**	101.0
Stress in ceramic [%]	100	**99.8**	**103.5**	**96.5**

Process flow





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Potentials of Virtual DoE technique

- Virtual DoE technique can significantly accelerate the design process of the electronic control units → lower development costs.
- Selection of the molding compound can be supported by numerical simulation taking into account variation of the material properties of the mold.
- For specific application such as LTCC, PCB or DBC substrate BOM can be defined based on the internal stress distribution and deformation, long time before first samples are manufactured.

Is it possible to use the results MOP directly in excel?

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